

BLM6112

Advanced Computer Architecture

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<http://www3.yildiz.edu.tr/~naydin>

Course Details

- Course Code : **BLM6112**
- Course Name : **Advanced Computer Architecture**
- Credit : **3**
- Level : **Graduate**
- Schedule : **Wednesday 09:00-11:50**
- Course web page:
http://www3.yildiz.edu.tr/~naydin/na_AcA.htm
- Instructors : **Nizamettin AYDIN**
Room: D-128
Email: naydin@yildiz.edu.tr, nizamettinaydin@gmail.com

Course Objective

- Learning properties of various computer architectures
- Learning about design (hardware) issues of high performance computing.

Course Content

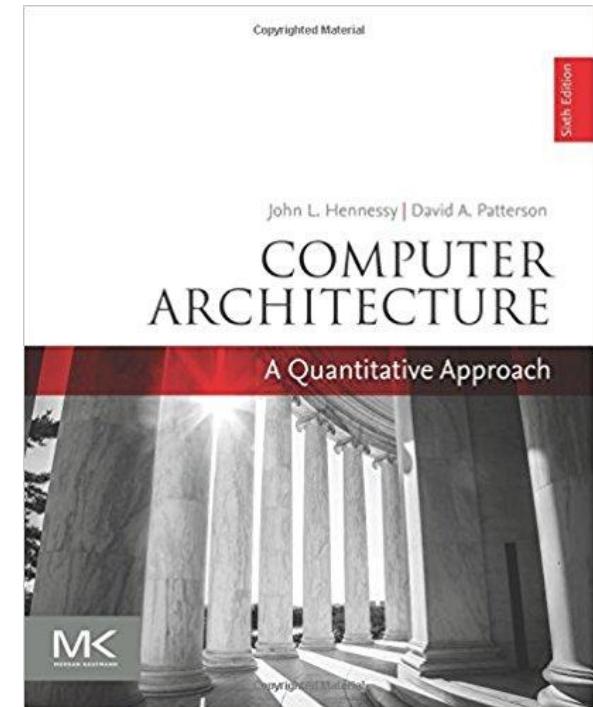
- Revision of Some Fundamental Concepts
- Computer System, Computer Evolution and Performance
- Cache, Cache Optimization, Virtual Memory
- Pipeline, Instruction-Level Parallelism, Data-Level Parallelism
- GPU Architectures, Thread-Level Parallelism, Multicore Processors.

Course Prerequisite

- Basic knowledge in
 - Computer organization
 - Digital circuit design
 - High-level language programming,
e.g. C or Java
 - Assembly programming, e.g.
Intelx86 or MC680xx.

Recommended Text(s)

- Main textbook:
 - Computer Architecture: A Quantitative Approach, John L. Hennessy, David A. Patterson
- Other recommended texts
 - Computer Organization and Architecture: Designing for Performance, William Stallings
 - Computer Organization and Design, David A. Patterson and John L. Hennessy
 - Computer System Architecture, M. Morris Mano
 - Logic and Computer Design Fundamentals, M. Morris Mano, Charles Kime
 - ...



Course Outline

- Revision of Fundamental Concepts
- Fundamentals of Quantitative Design & Analysis (**Chapter 1**)
- Instruction Set Principles (**Appendix A**)
- Instruction Pipelining (**Appendix C**)
- Memory Hierarchy Design (**Appendix B & Chapter 2**)
- Instruction-Level Parallelism (**Chapter 3**)
- Data-Level Parallelism (**Chapter 4**)
- Thread-Level Parallelism (**Chapter 5**)

Assessment

- Midterm : 30%
- Final : 40%
- Project : 15%
- Homework : 15%

Rules of the Conduct

- No eating /drinking in class
 - *except water*
- Cell phones must be kept outside of class or switched-off during class
- No talking with your peers
- No late arrival or early leave to/from the lecture
- No web surfing and/or unrelated use of computers
 - when computers are used in class or lab

Rules of the Conduct

- You are responsible for checking the class web page often for announcements.
 - http://www3.yildiz.edu.tr/~naydin/na_AcA.htm
- Academic dishonesty and cheating
 - will not be tolerated
 - will be dealt with according to university rules and regulations
 - <http://www.yok.gov.tr/content/view/475/>
 - Presenting any work that does not belong to you is also considered academic dishonesty.

Electronics Systems

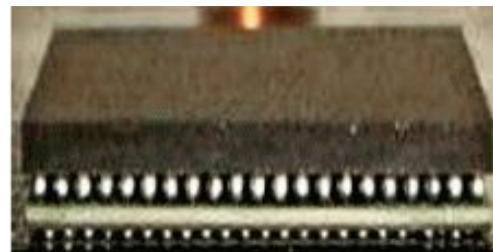
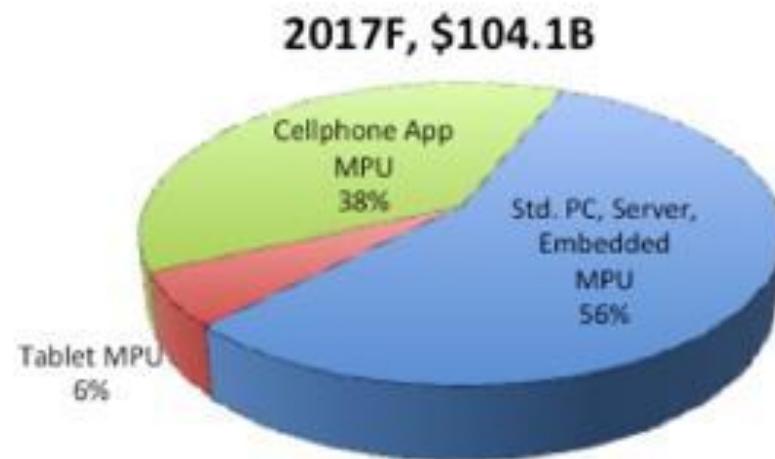
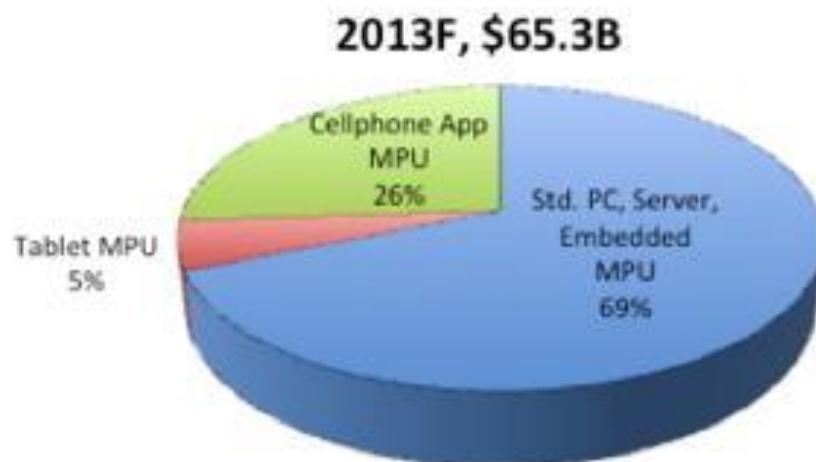


The Computer Revolution

- Progress in computer technology
 - Underpinned by Moore's Law
- Makes novel applications feasible
 - Computers in automobiles
 - Cell phones
 - Human genome project
 - World Wide Web
 - Search Engines
- Computers are pervasive

The Processor Market

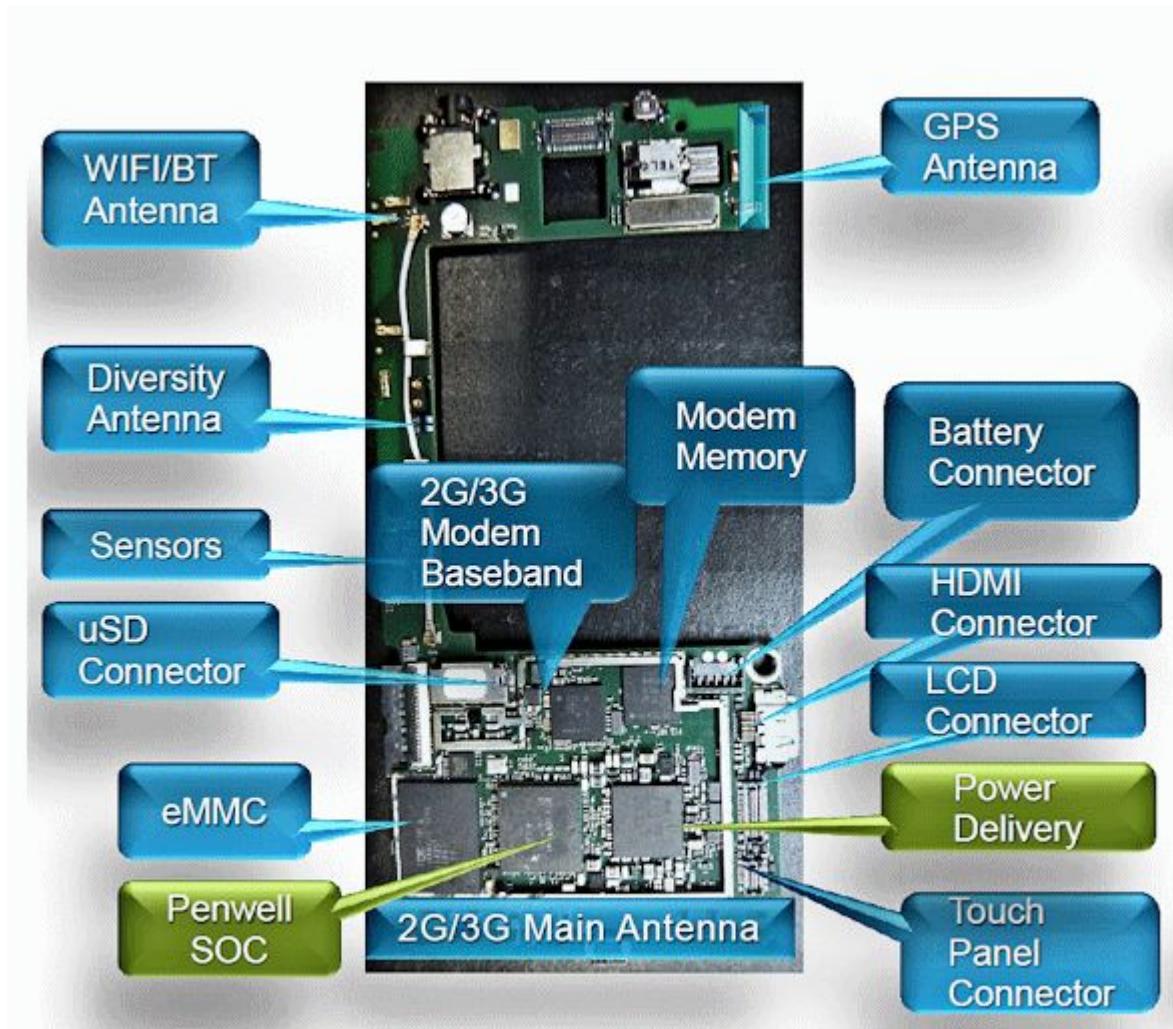
Microprocessor Sales by Type (%)



Cell Phones!!



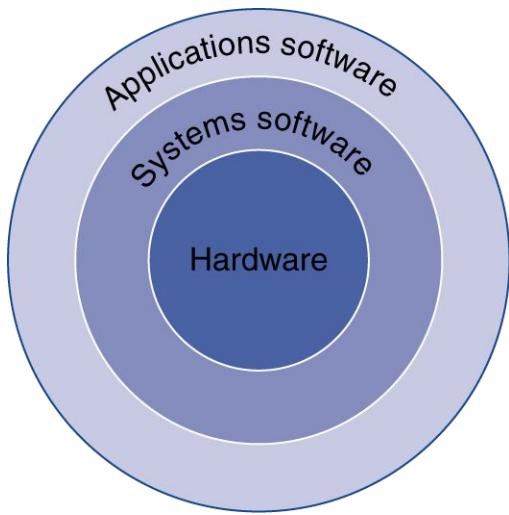
Cell Phones!!



Classes of Computers

- Desktop computers
 - General purpose, variety of software
 - Subject to cost/performance tradeoff
- Server computers
 - Network based
 - High capacity, performance, reliability
- Embedded computers
 - Hidden as components of systems
 - Stringent power/performance/cost constraints
- Supercomputers

Below Your Program



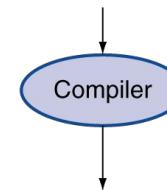
- Application software
 - Written in high-level language
- System software
 - Compiler: translates HLL code to machine code
 - Operating System: service code
 - Handling input/output
 - Managing memory and storage
 - Scheduling tasks & sharing resources
- Hardware
 - Processor, memory, I/O controllers

Levels of Program Code

- High-level language
 - Level of abstraction closer to problem domain
 - Provides for productivity and portability
- Assembly language
 - Textual representation of instructions
- Hardware representation
 - Binary digits (bits)
 - Encoded instructions and data

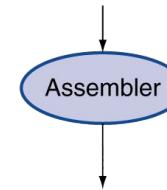
High-level language program (in C)

```
swap(int v[], int k)
{int temp;
 temp = v[k];
 v[k] = v[k+1];
 v[k+1] = temp;
}
```



Assembly language program (for MIPS)

```
swap:
    muli $2, $5,4
    add $2, $4,$2
    lw $15, 0($2)
    lw $16, 4($2)
    sw $16, 0($2)
    sw $15, 4($2)
    jr $31
```

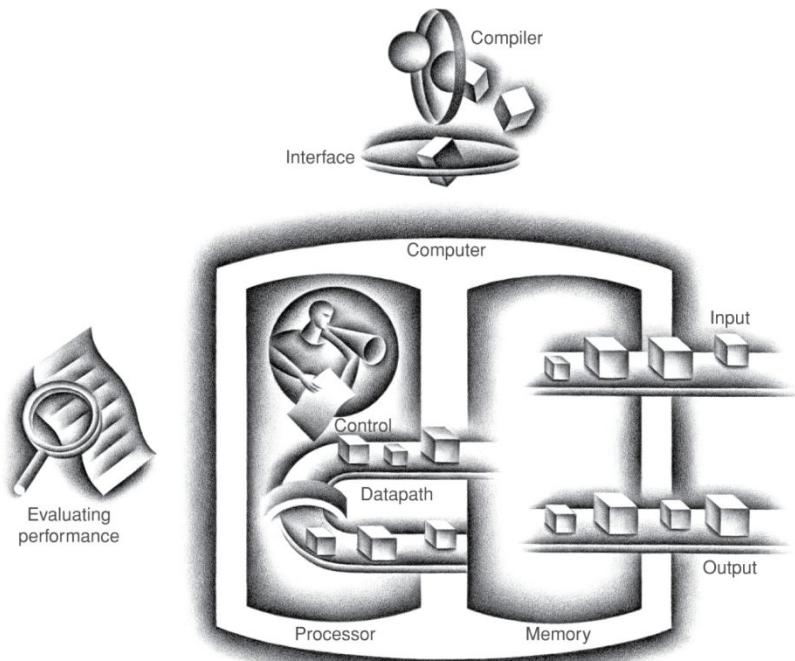


Binary machine language program (for MIPS)

```
000000000101000010000000000000110000
000000000000110000000110000001000001
10001100011000100000000000000000000000
100011001111001000000000000000000000000
1010110011110010000000000000000000000000
1010110001100010000000000000000000000000
00000001111100000000000000000000000000000
```

Below Your Program

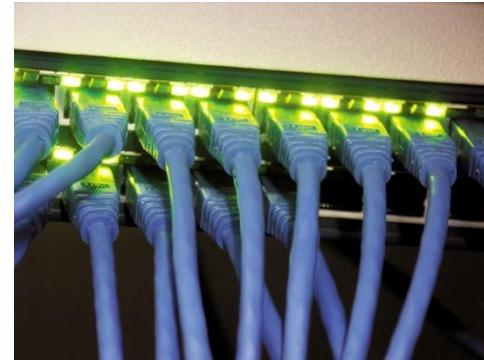
The BIG Picture



- Same components for all kinds of computer
 - Desktop, server, embedded
- Input/output includes
 - User-interface devices
 - Display, keyboard, mouse
 - Storage devices
 - Hard disk, CD/DVD, flash
 - Network adapters
 - For communicating with other computers

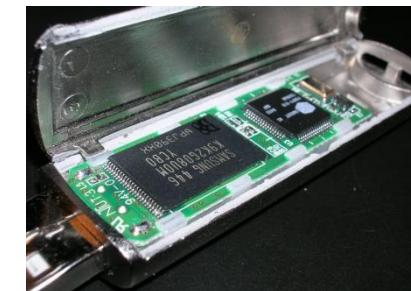
Networks

- Communication and resource sharing
- Local area network (LAN): Ethernet
 - Within a building
- Wide area network (WAN: the Internet)
- Wireless network: WiFi, Bluetooth

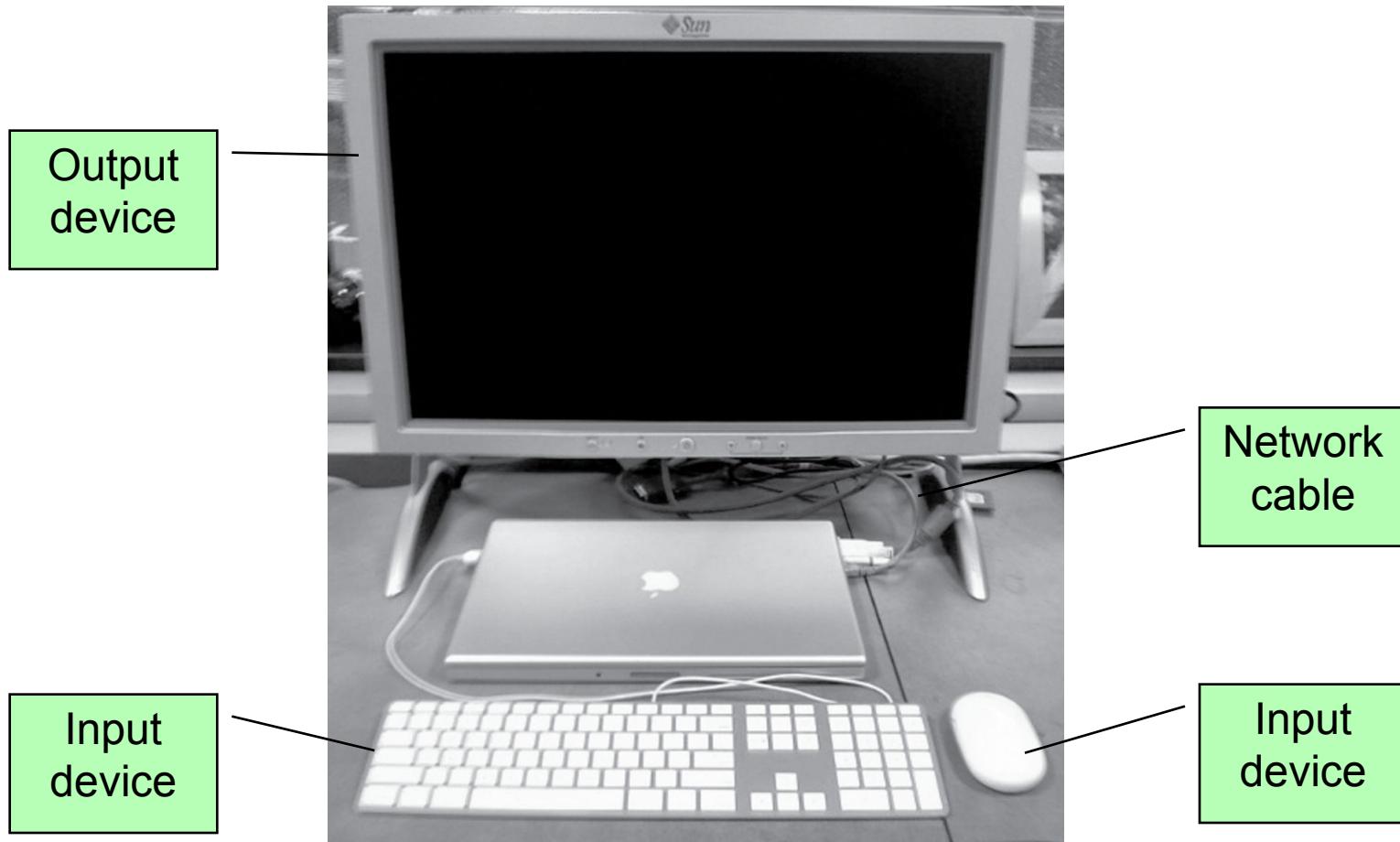


Networks

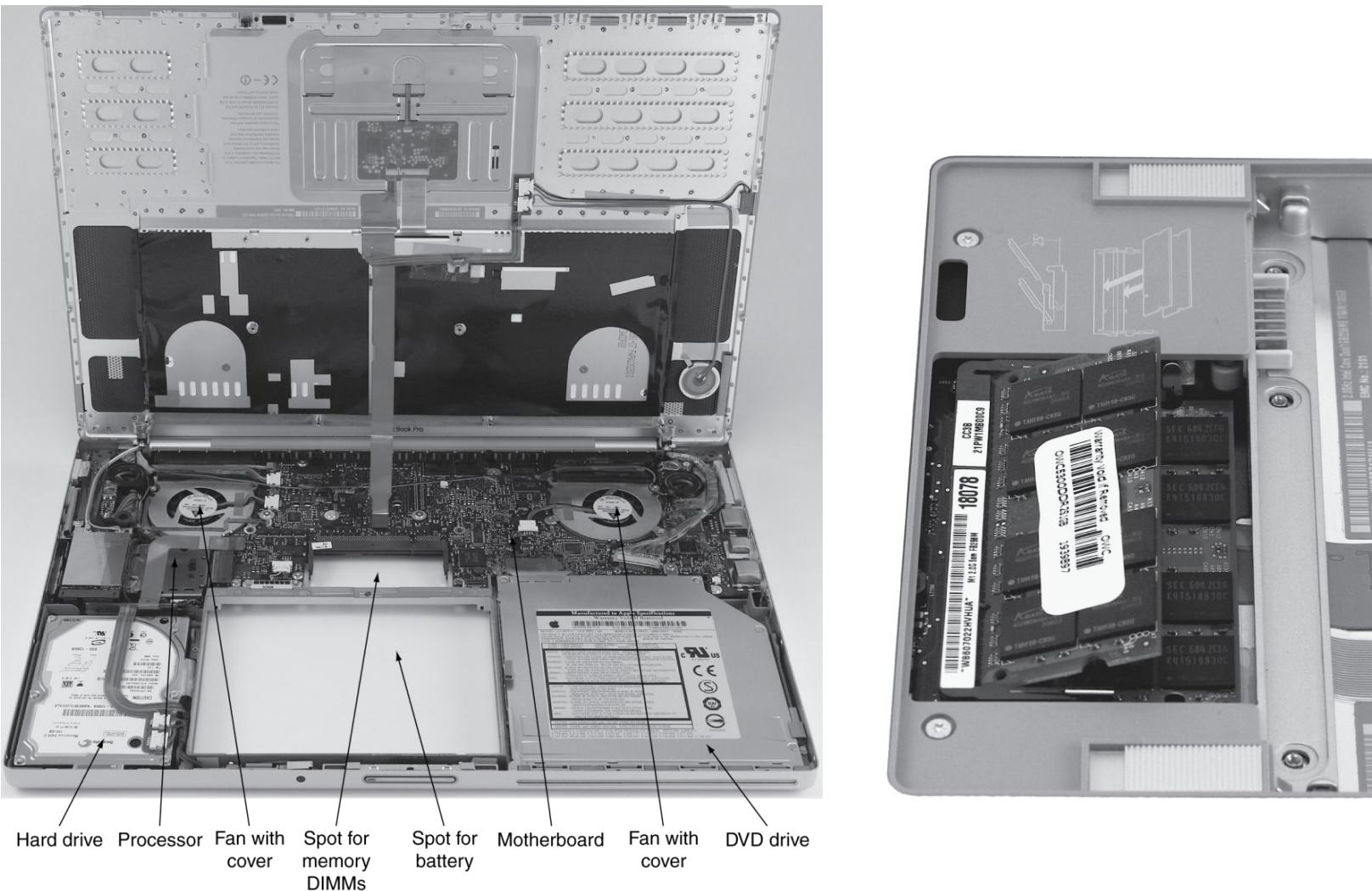
- Volatile main memory
 - Loses instructions and data when power off
- Non-volatile secondary memory
 - Magnetic disk
 - Flash memory
 - Optical disk (CDROM, DVD)



Anatomy of a Computer

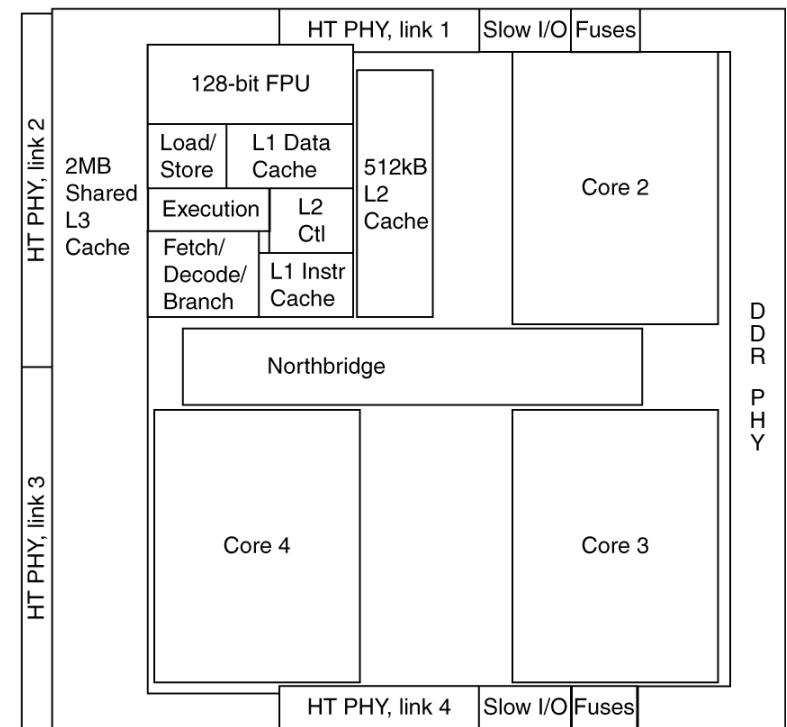
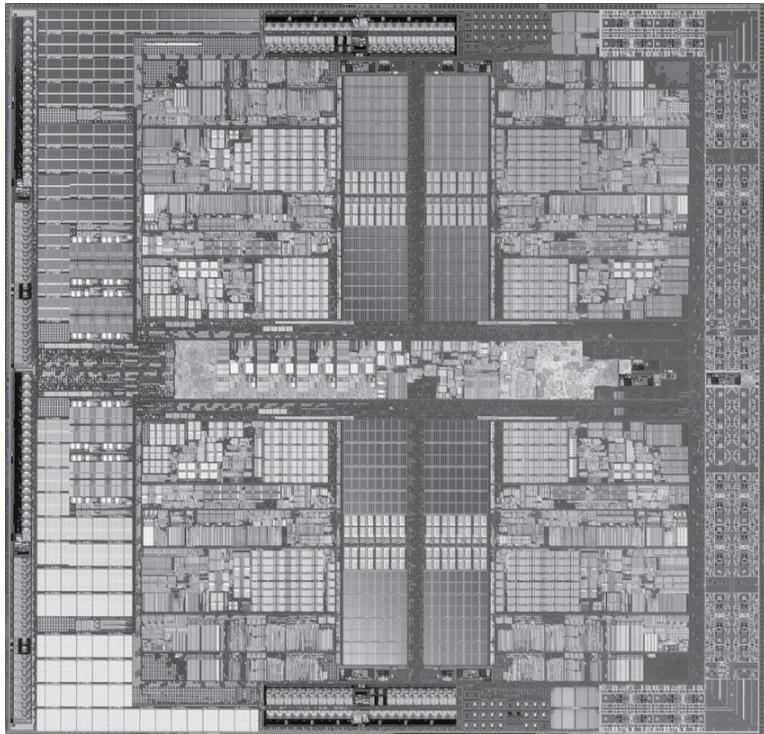


Opening the Box

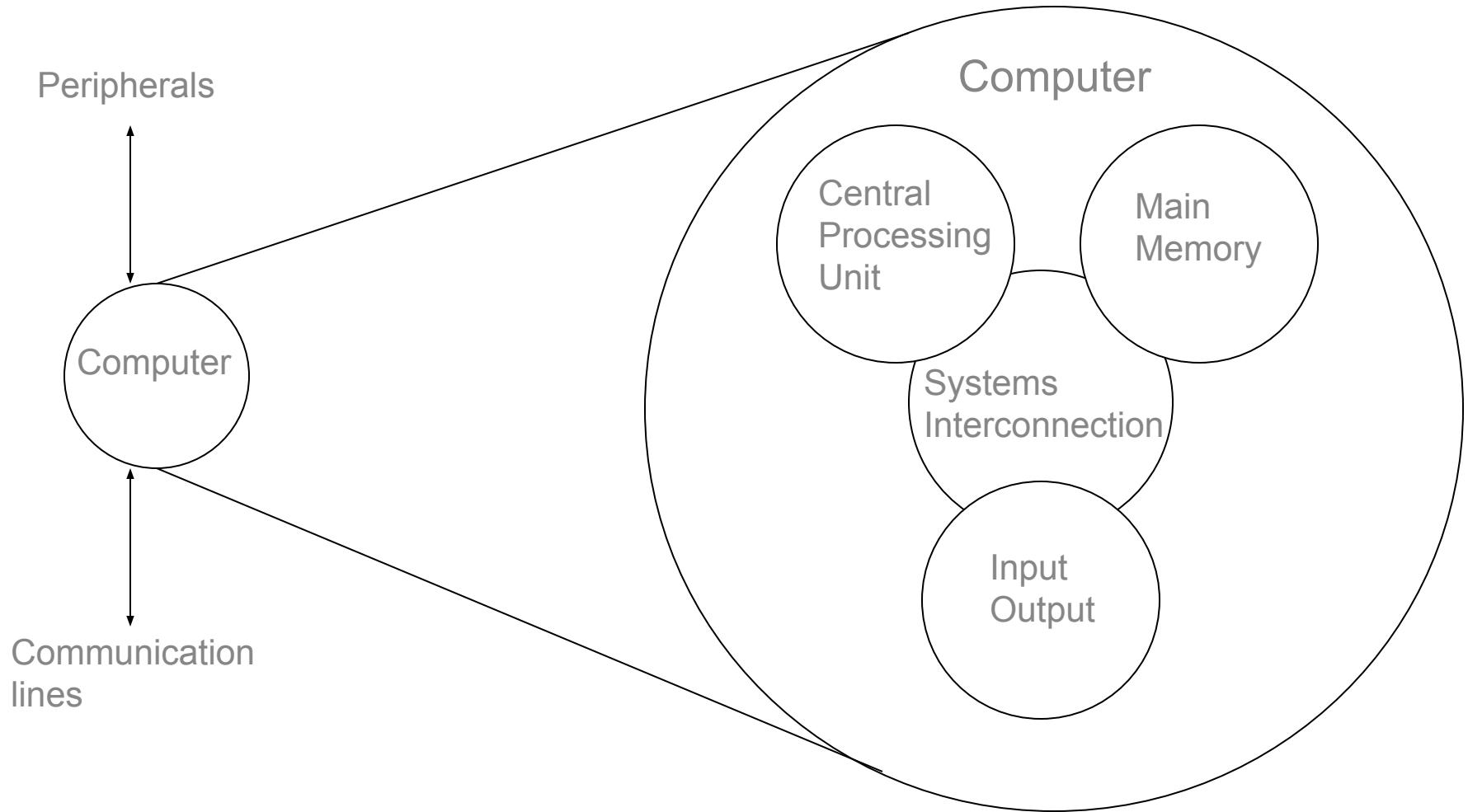


The Processor

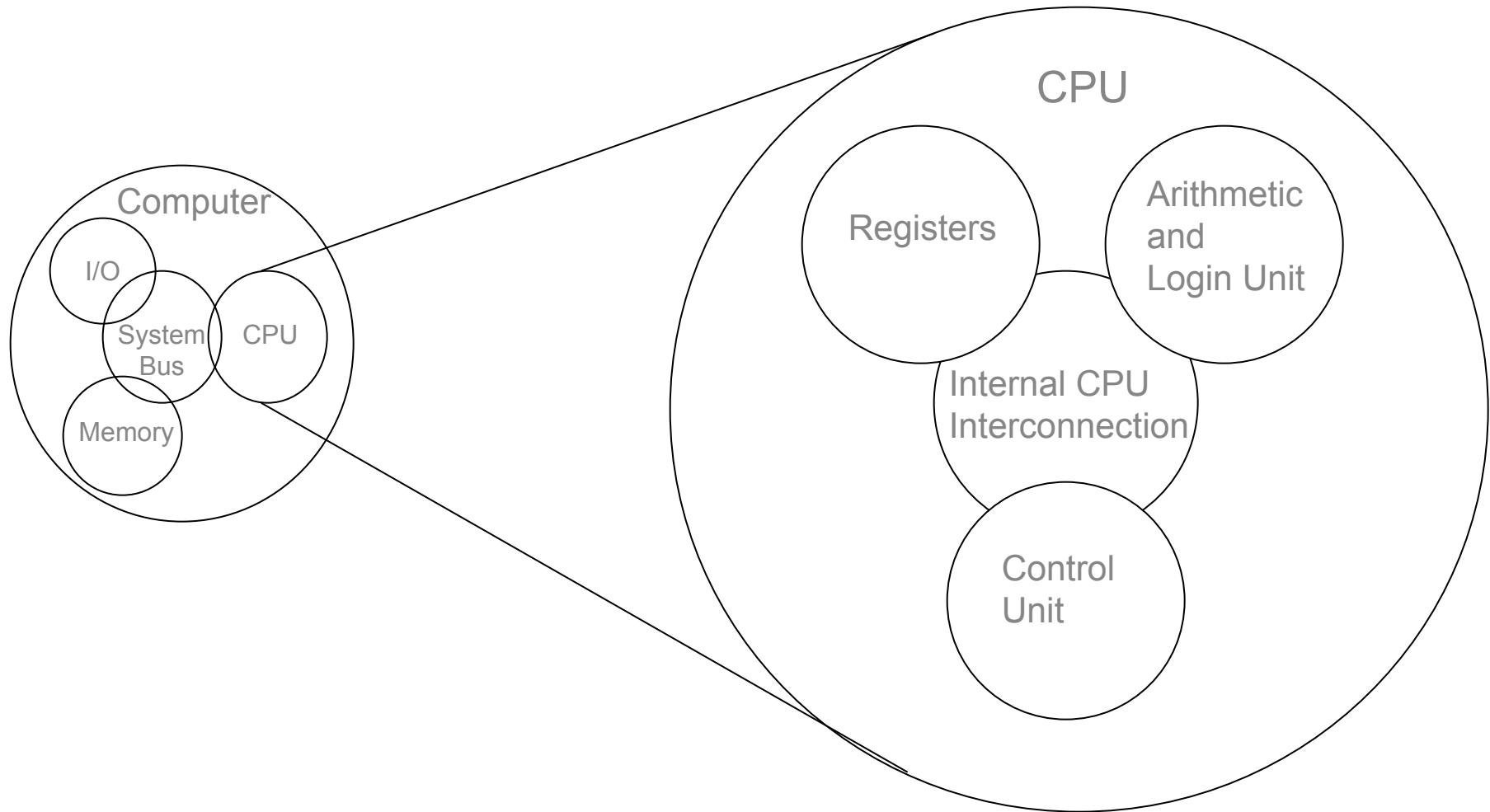
- AMD Barcelona: 4 processor cores



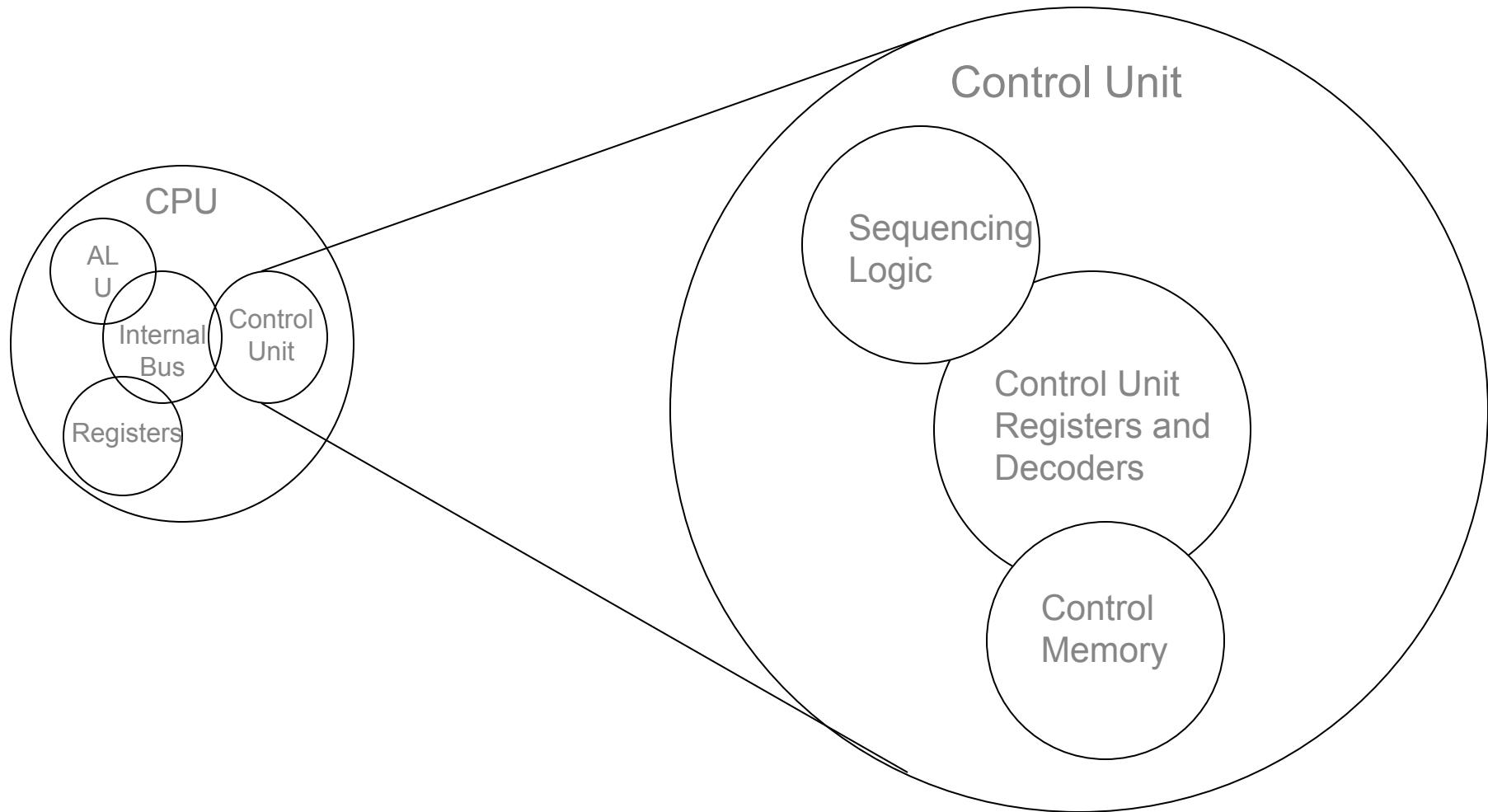
Inside the Computer



Inside the Processor (CPU)

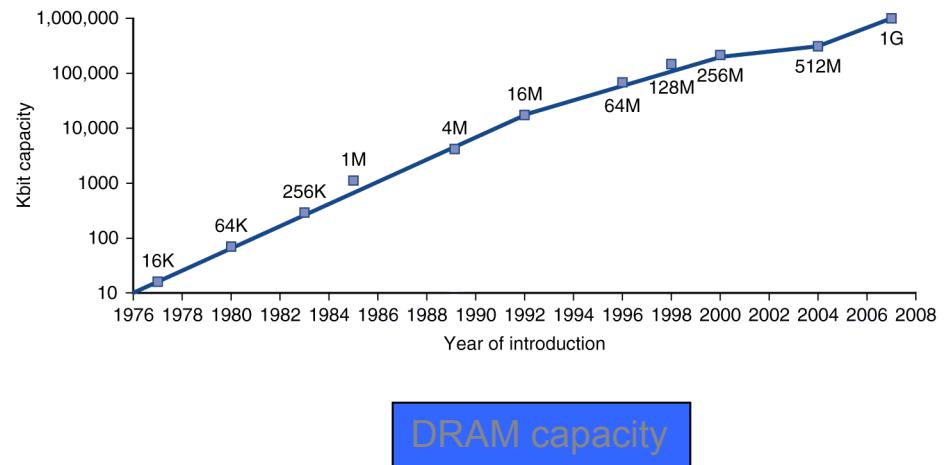


Inside the Control Unit



Technology Trends

- Electronics technology continues to evolve
 - Increased capacity and performance
 - Reduced cost



Year	Technology	Relative performance/cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit (IC)	900
1995	Very large scale IC (VLSI)	2,400,000
2005	Ultra large scale IC	6,200,000,000



Charles Babbage 1791-1871

Lucasian Professor of Mathematics
Cambridge University, 1827-1839

Arvind
February 3, 1999
6.823, L1-3

Difference Engine 1823

Analytic Engine 1833
The forerunner of modern digital computer!

Application?

Mathematical Tables - Astronomy
Nautical Tables - Navy

Background

Any continuous function can be approximated
by a polynomial --- Weierstrass

Technology

mechanical - gears, Jacquard's loom,
simple calculators



Difference Engine

- 1823** - Babbage's paper is published
- 1834** - The paper is read by Scheutz & his son in Sweden
- 1842** - Babbage gives up the idea of building it;
(he is onto Analytic Engine!)
- 1855** - Scheutz displays his machine at the Paris World Fare
 - Can compute any 6th degree polynomial
 - Speed: 33 to 44 32-digit numbers per minute!

Now the machine is at the Smithsonian



Arvind
February 3, 1999
6.823, L1-9

Linear Equation Solver

John Atanasoff, Iowa State University

1930's: Atanasoff built the Linear Equation Solver.
It had 300 tubes!

Application:
Linear and Integral differential equations

Background:
Vannevar Bush's Differential Analyzer
--- *an analog computer*

Technology:
Tubes and Electromechanical relays

Atanasoff decided that the correct mode of computation was by electronic digital means.



ENIAC and EDVAC

The first conception of a *stored program computer*

ENIAC 1946, 48

EDVAC 1948

concept only

Arvind
February 3, 1999
6.823, L1-10

Players brought together by the WW-2 effort

- Eckert & Mauchley, University of Pennsylvania
- John von Neumann, Princeton University

Application:

Ballistic calculations

angle = f (location, tail wind, cross wind,
air density, temperature, weight of shell,
propellant charge, ...)

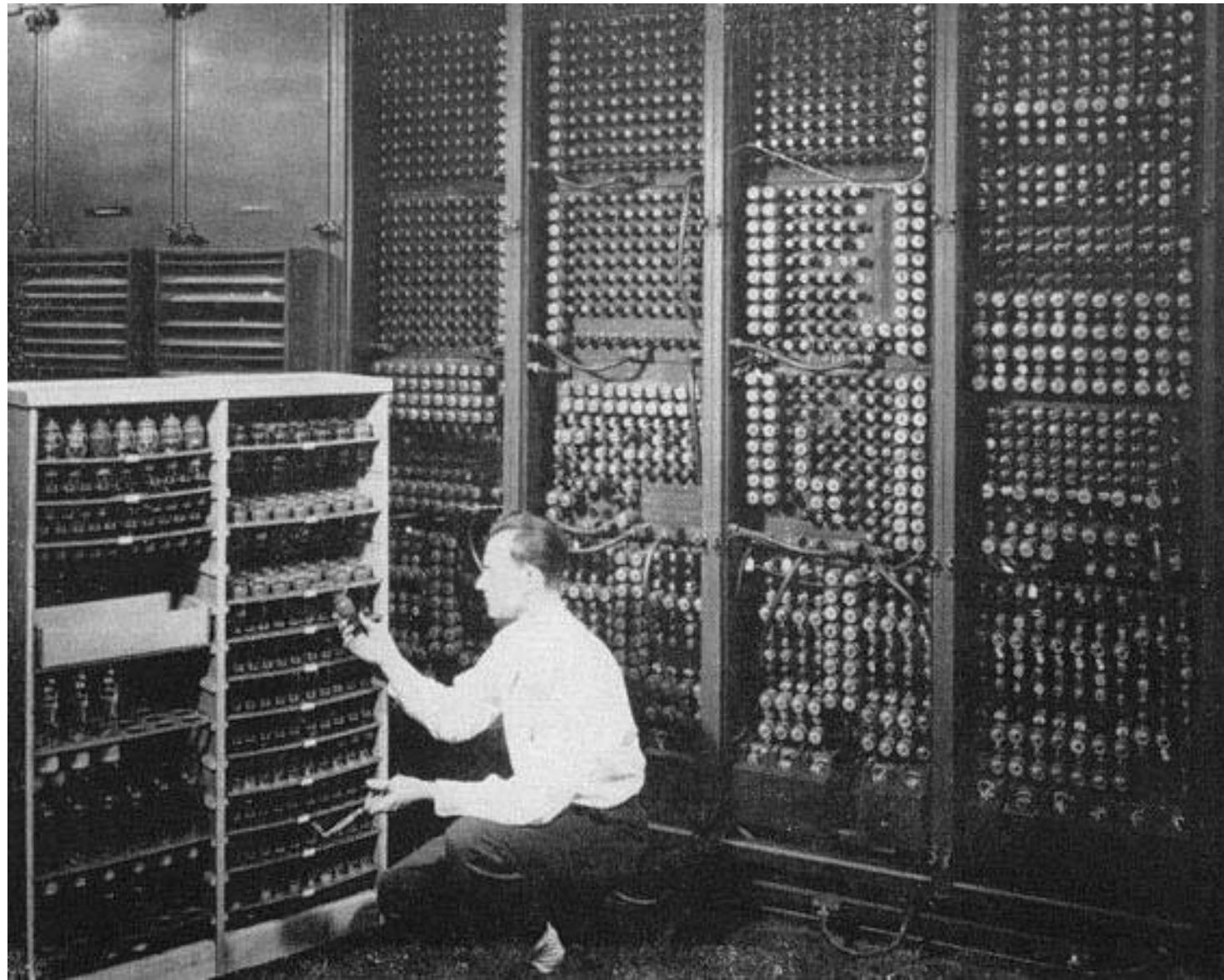


Technology:

tubes, relays, electromechanical delays,
mercury delay lines,...

Developed the concept of *stored program computer*
⇒ *program can be manipulated as data*

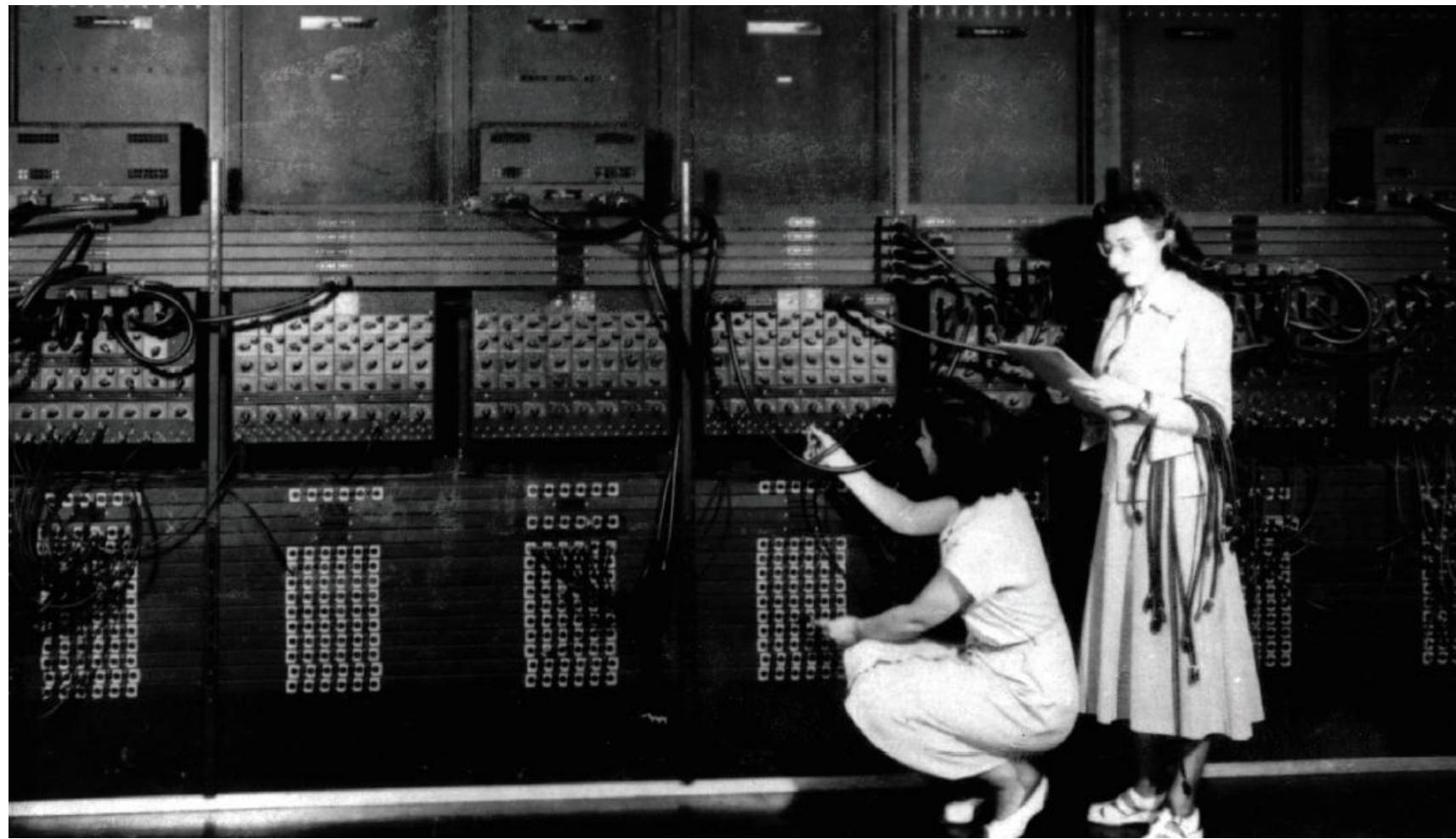
Eniac



Eniac (find the OS?)

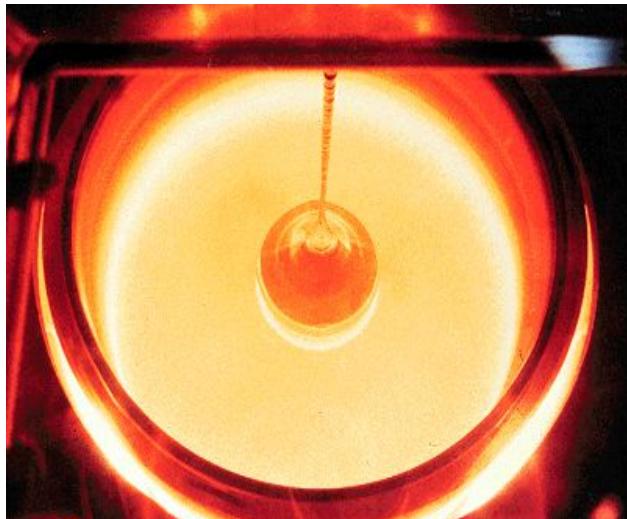


Eniac (find the Programmer?)

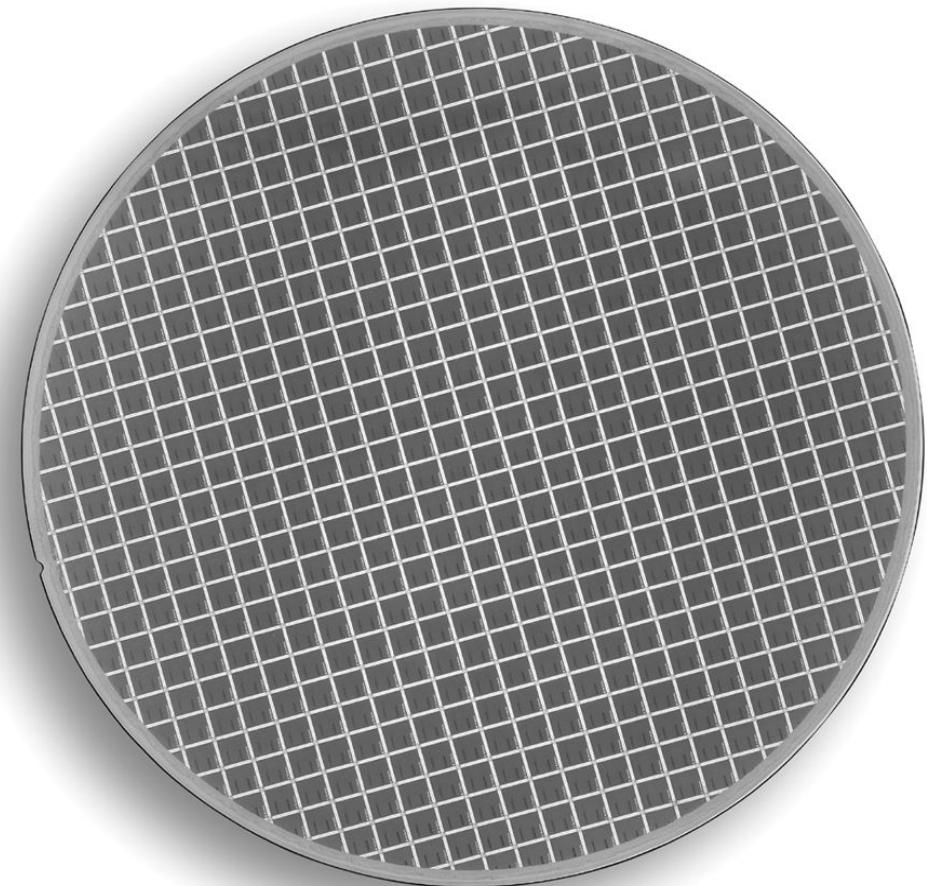


Integrated Circuits: wafer (564 dies)

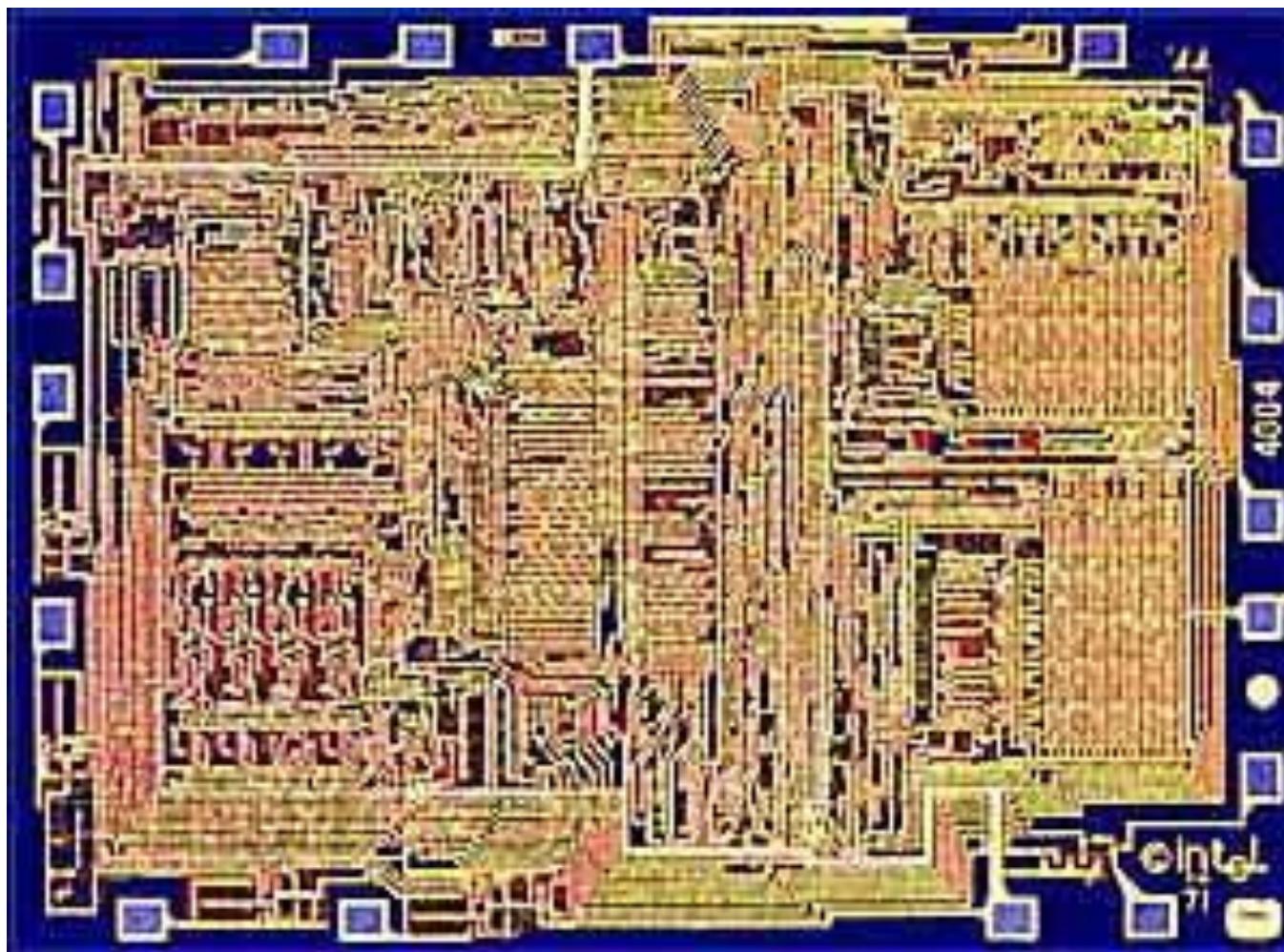
Drawing single-crystal
Si ingot from furnace....



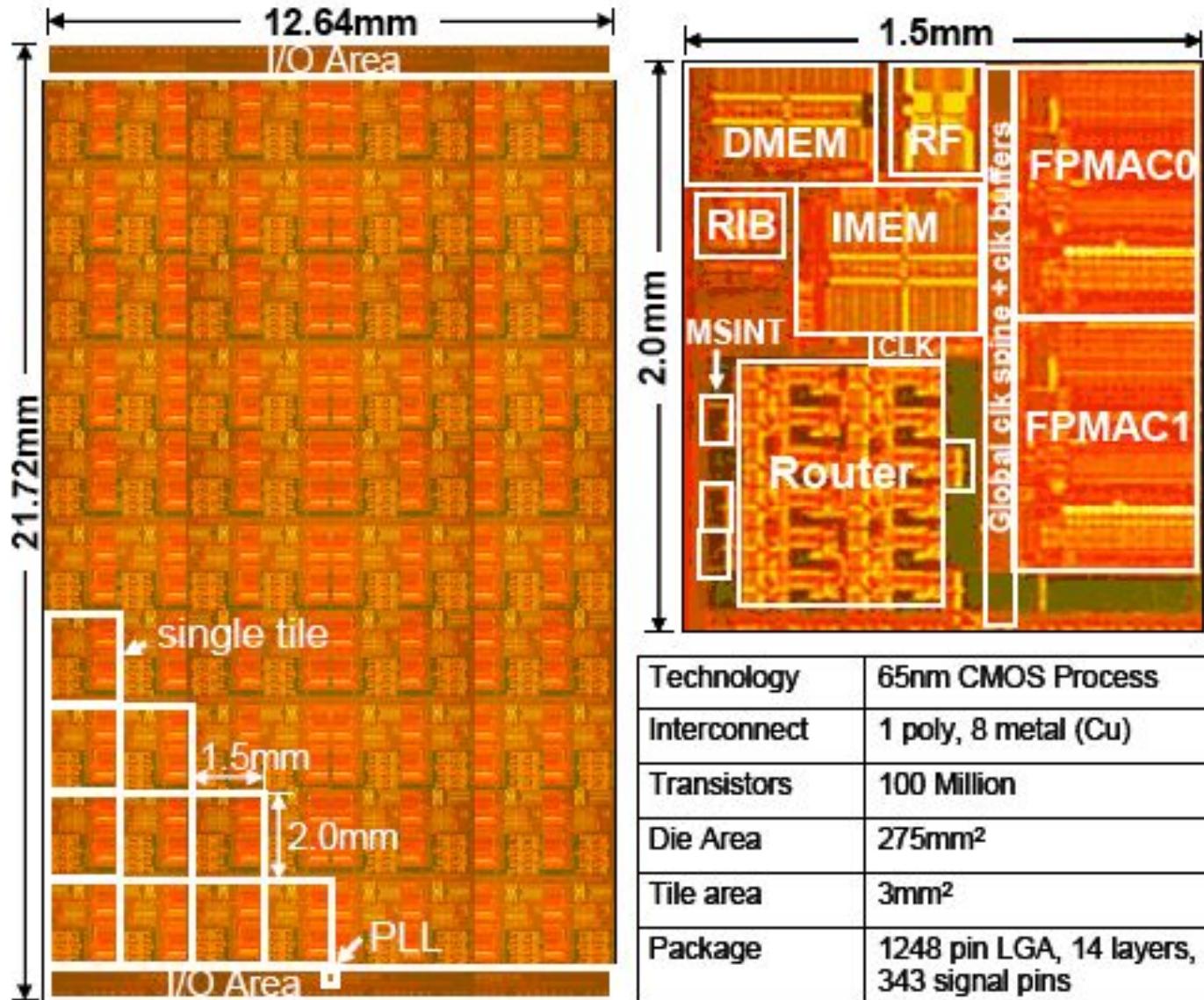
Then, slice into wafers and pattern it...



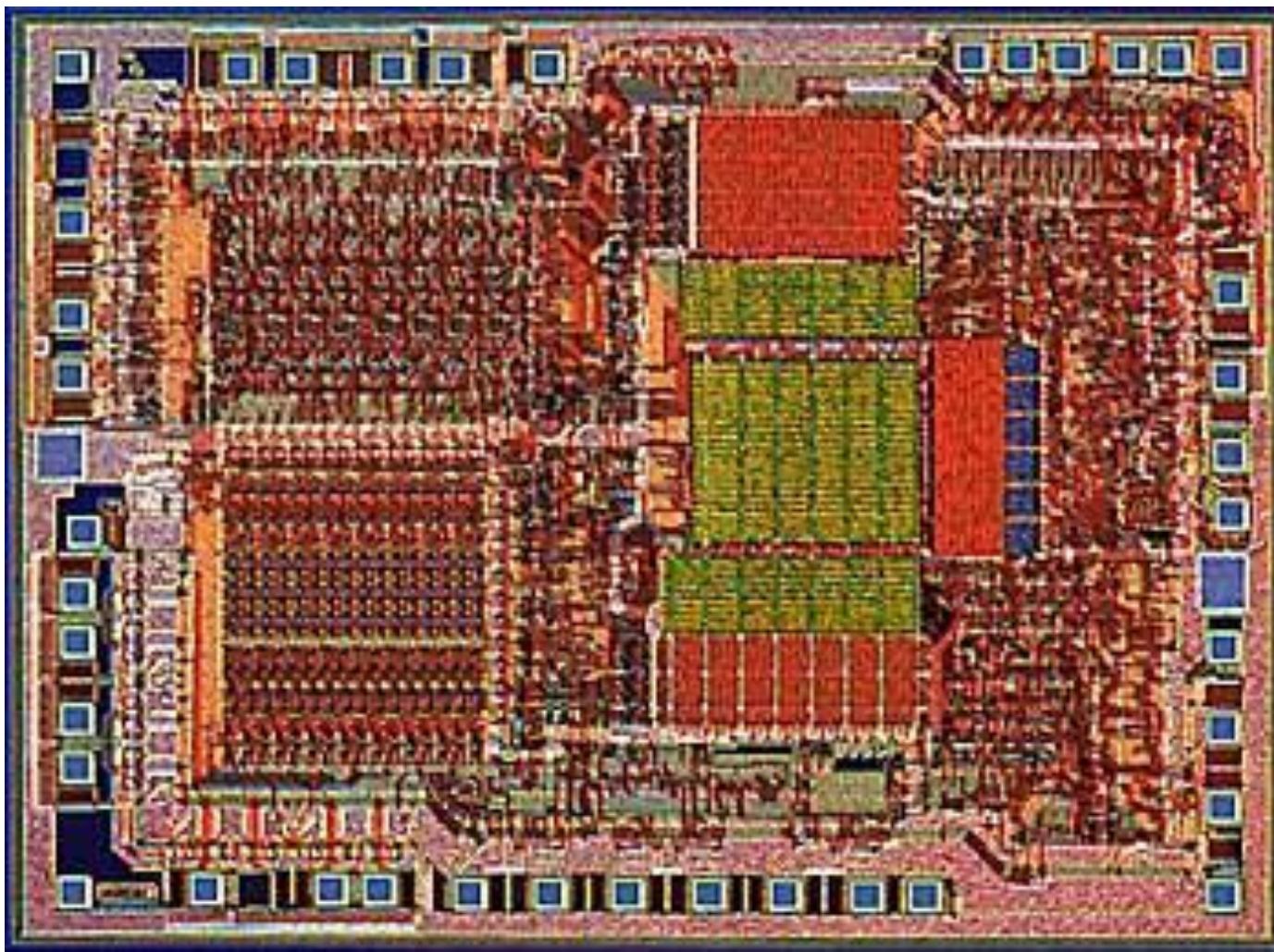
In the beginning Intel 4004 (4-bit)



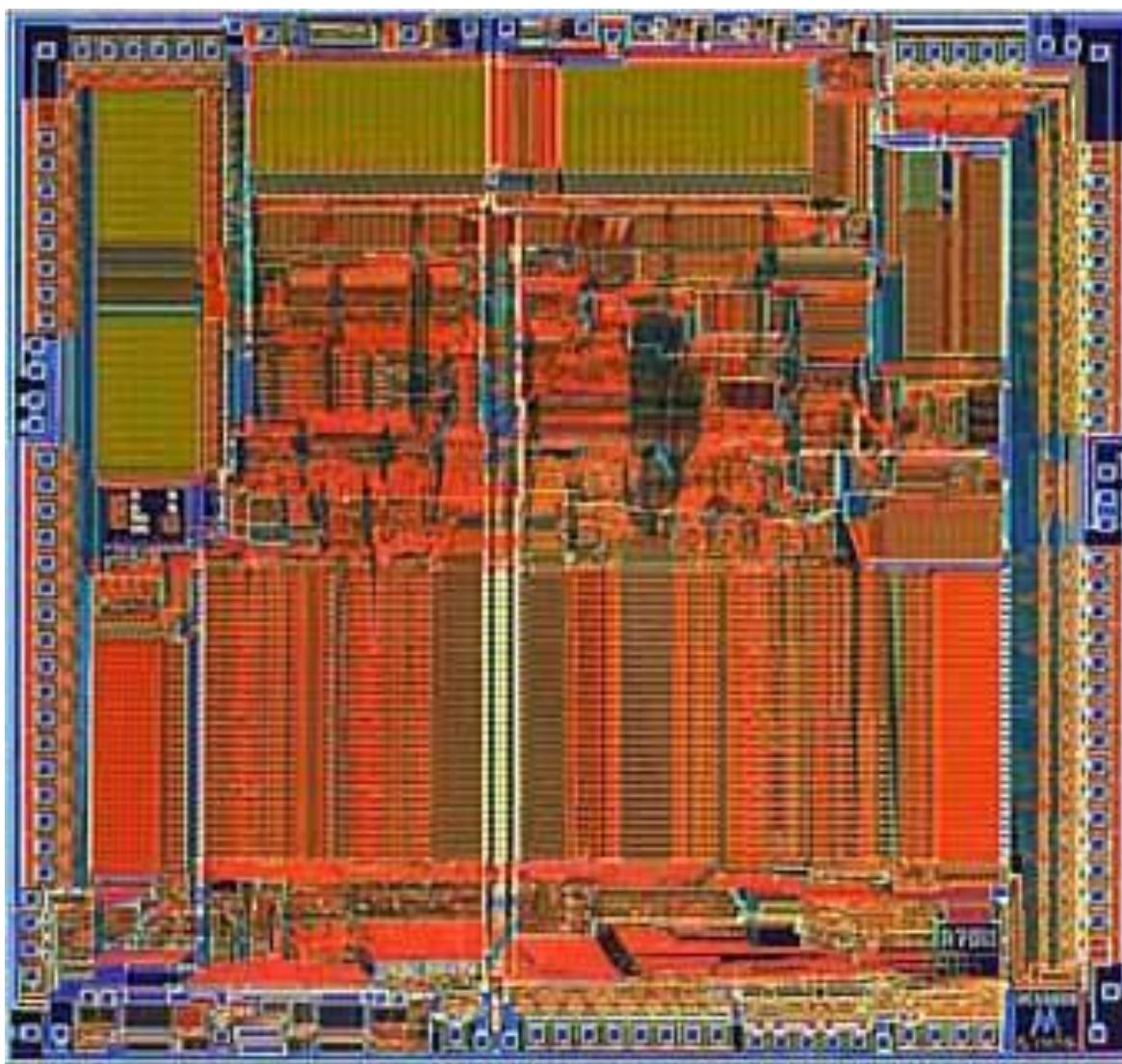
Intel 8080 (8-bit)



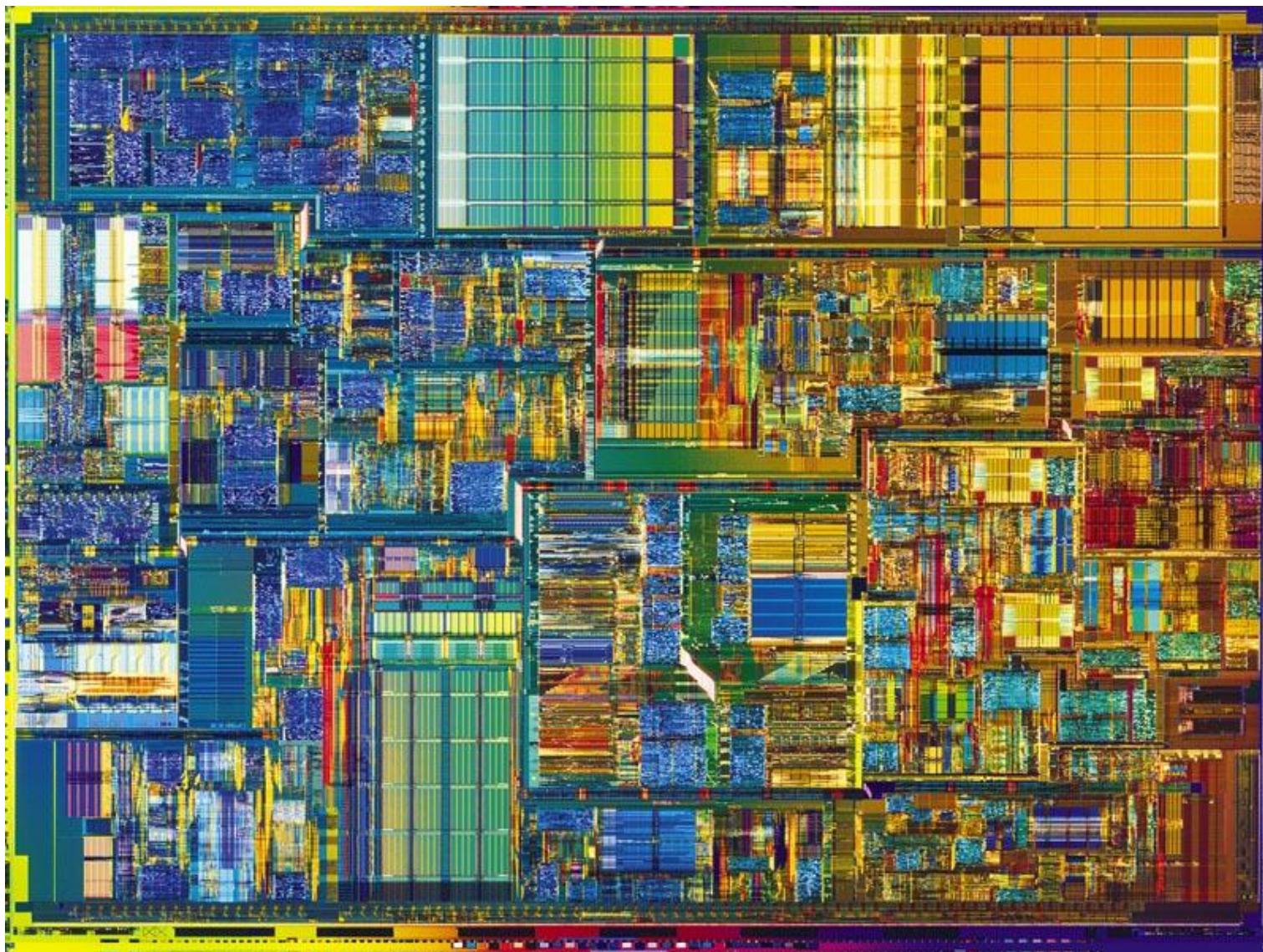
Intel 8086 (16-bit)



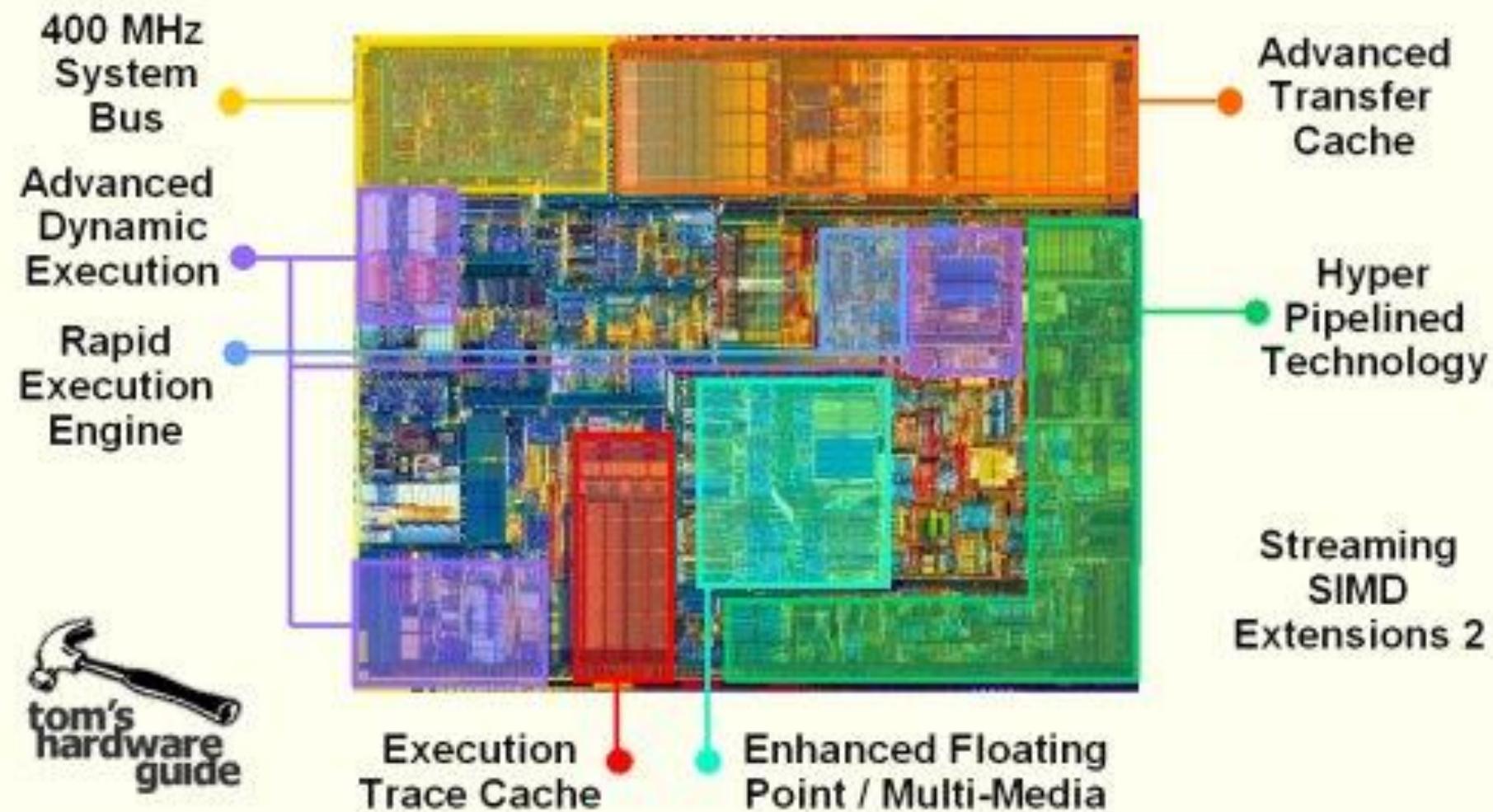
Motorola 68000 (32-bit)



Pentium 4 (64-bit)



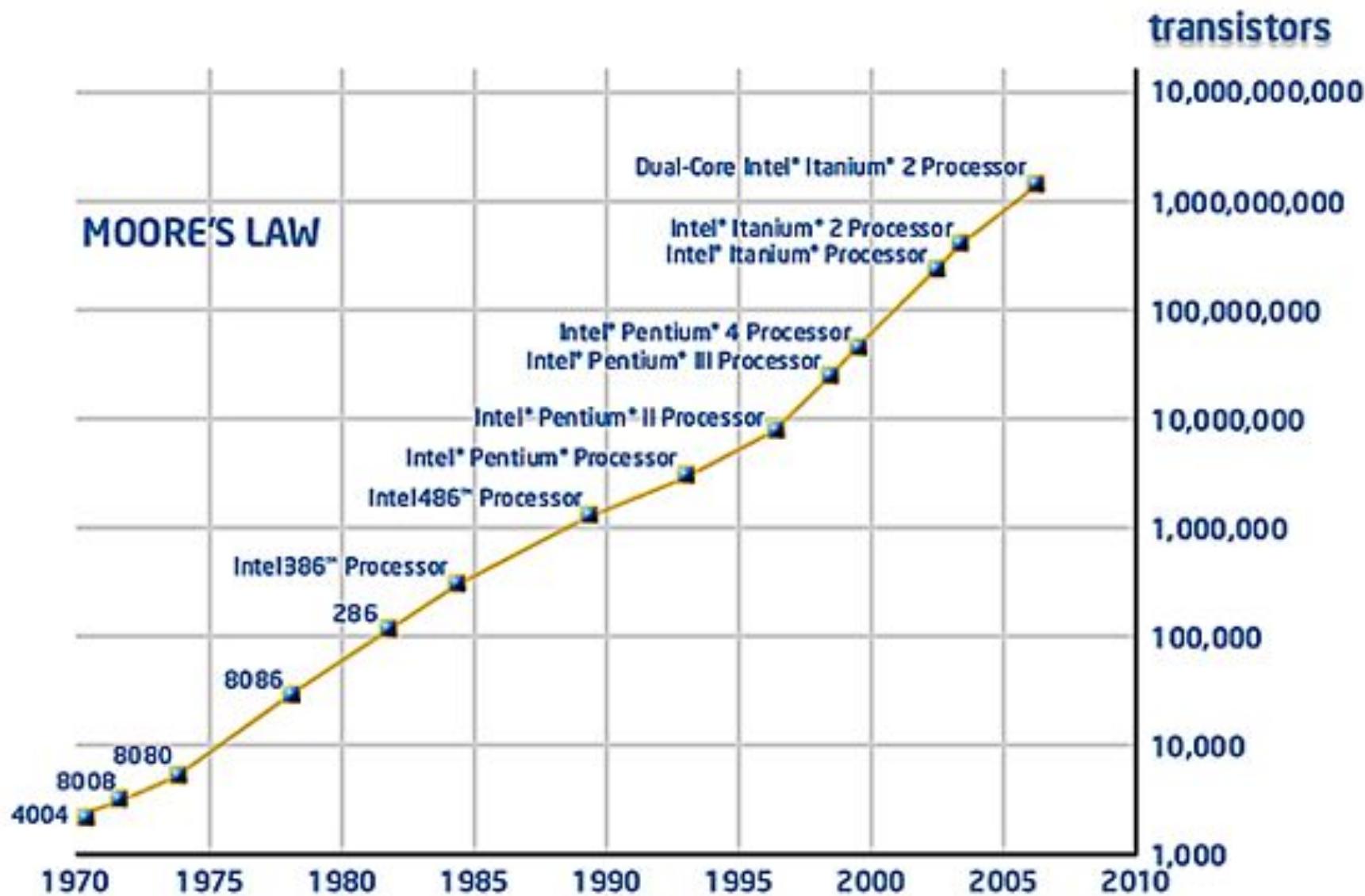
Pentium 4 chip breakdown



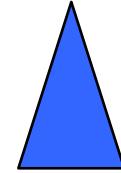
Intel Microprocessor Evolution

	Year/Month	Clock =1/tc.	Transistors.	Micras
I4004	1971/11	108 KHz.	2300	10
I8080	1974/04	2 MHz.	6000	6
I8086	1978/06	10 MHz.	29000	3
I80286	1982/02	12 MHz.	0.13 m.	1.50
I486DX	1989/04	25 MHz.	1.2 m.	1
Intel DX2	1992/03	100 MHz.	1.6 m	0.8
Pentium	1993/03	60 MHz.	3.1 m	0.8
Pentium Pro	1995/11	200 MHz.	5.5 m	0.35
Pentium II	1998/	450 MHz	7.5 m.	0.25
Pentium III	2000/01	1000 MHz.	28 m.	0.18
P4	2000/09	1400 MHz.	42 m.	0.18

Technology Trends



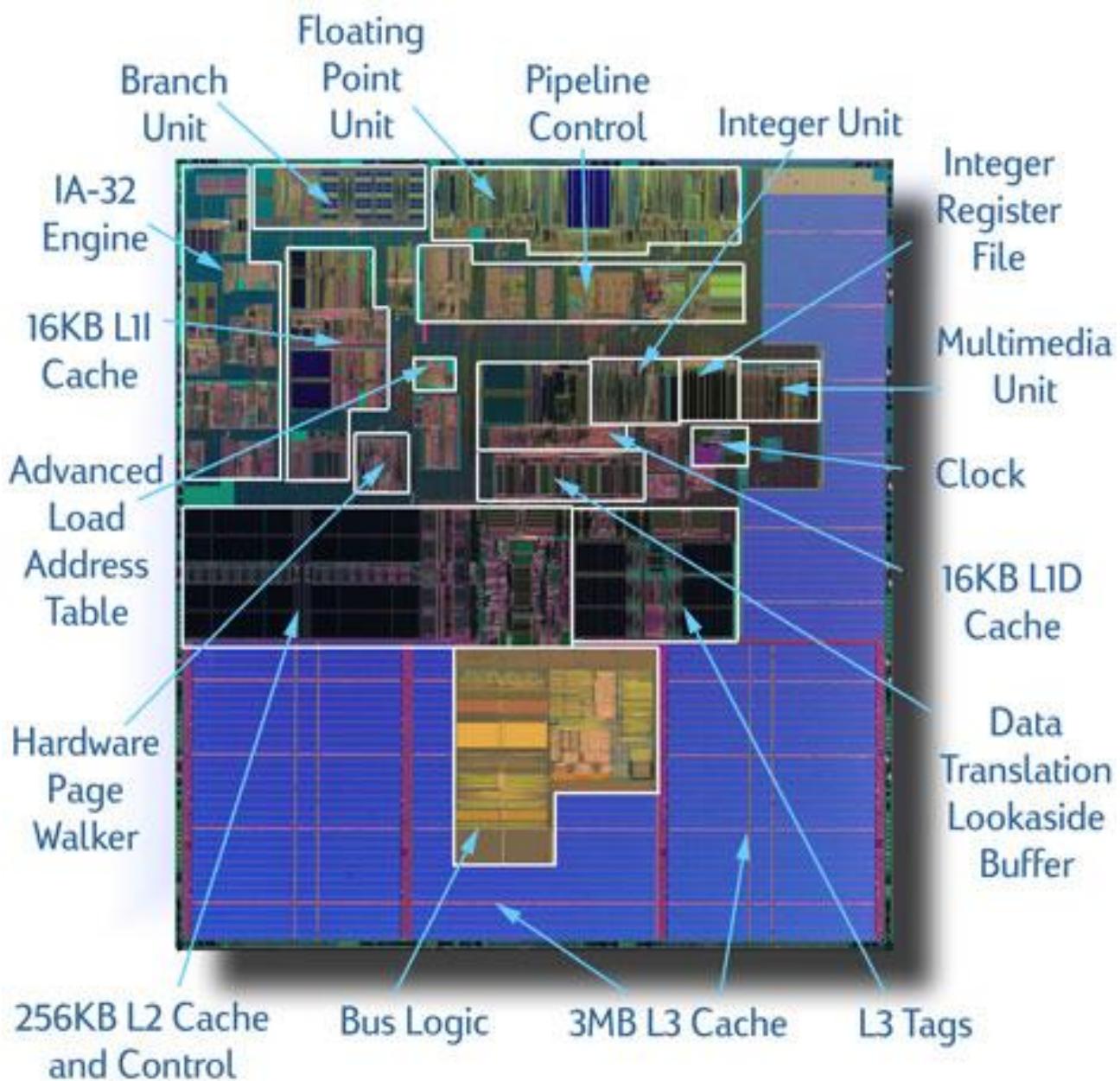
Intel IA-64 / Itanium



Explicit Parallel Instruction Computer

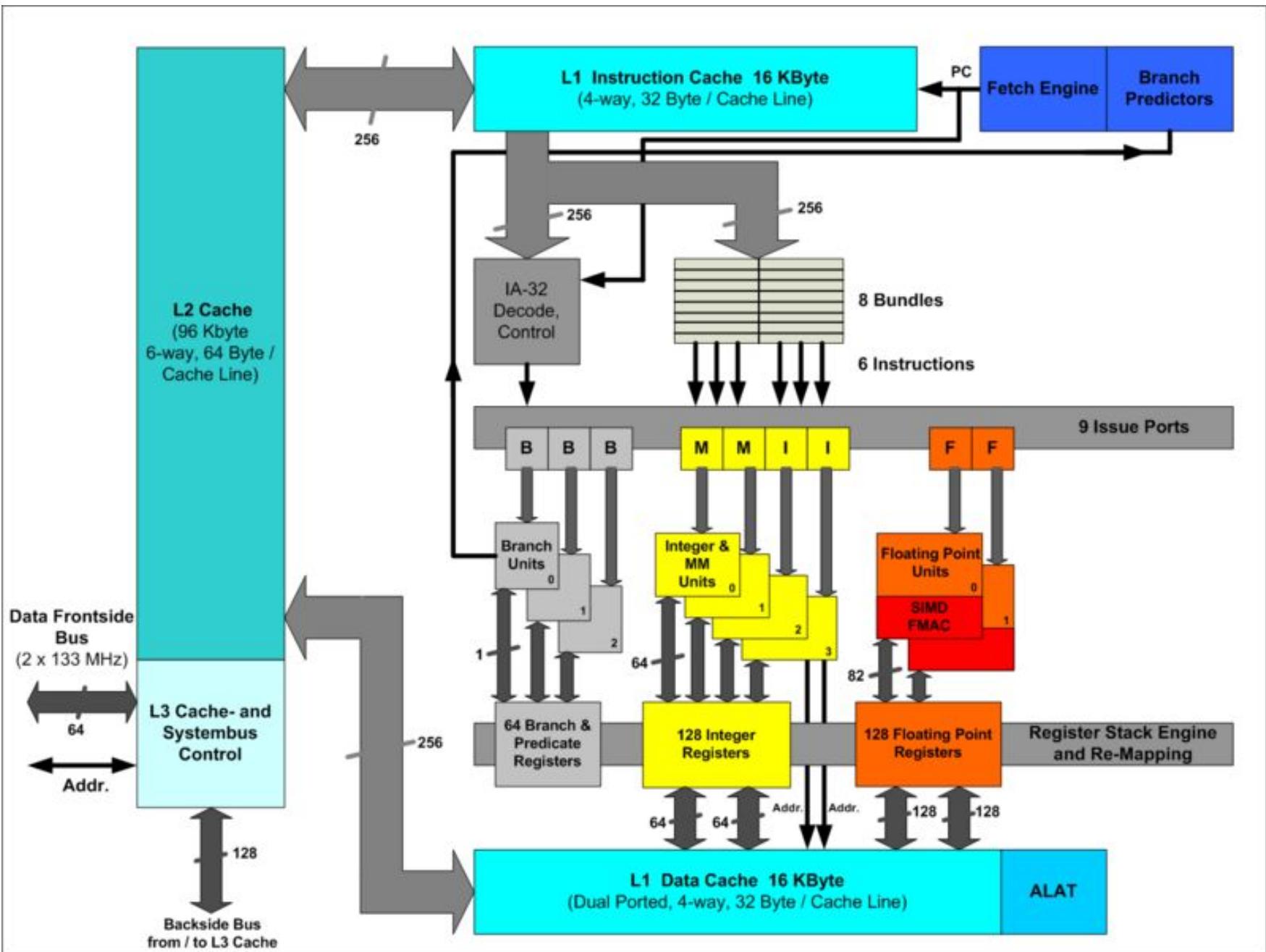
- IA-64
- Implementations: Merced (2001), McKinley (2002), Montecito (2 core, 2006), Tukwila (4-core 2009), Poulson (Q4, 2009, 8-core)
- Architecture is now called Itanium



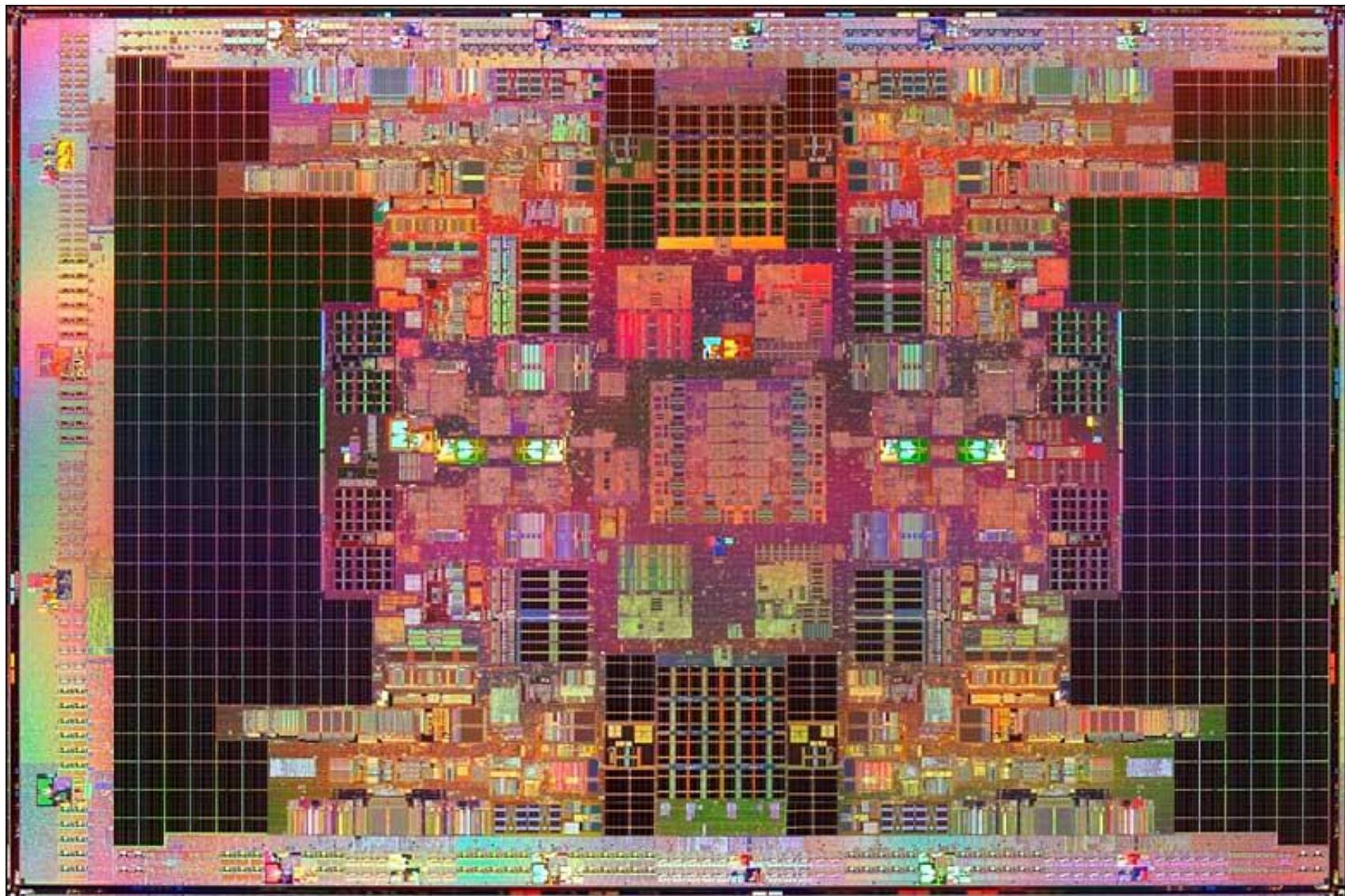


McKinley microprocessor

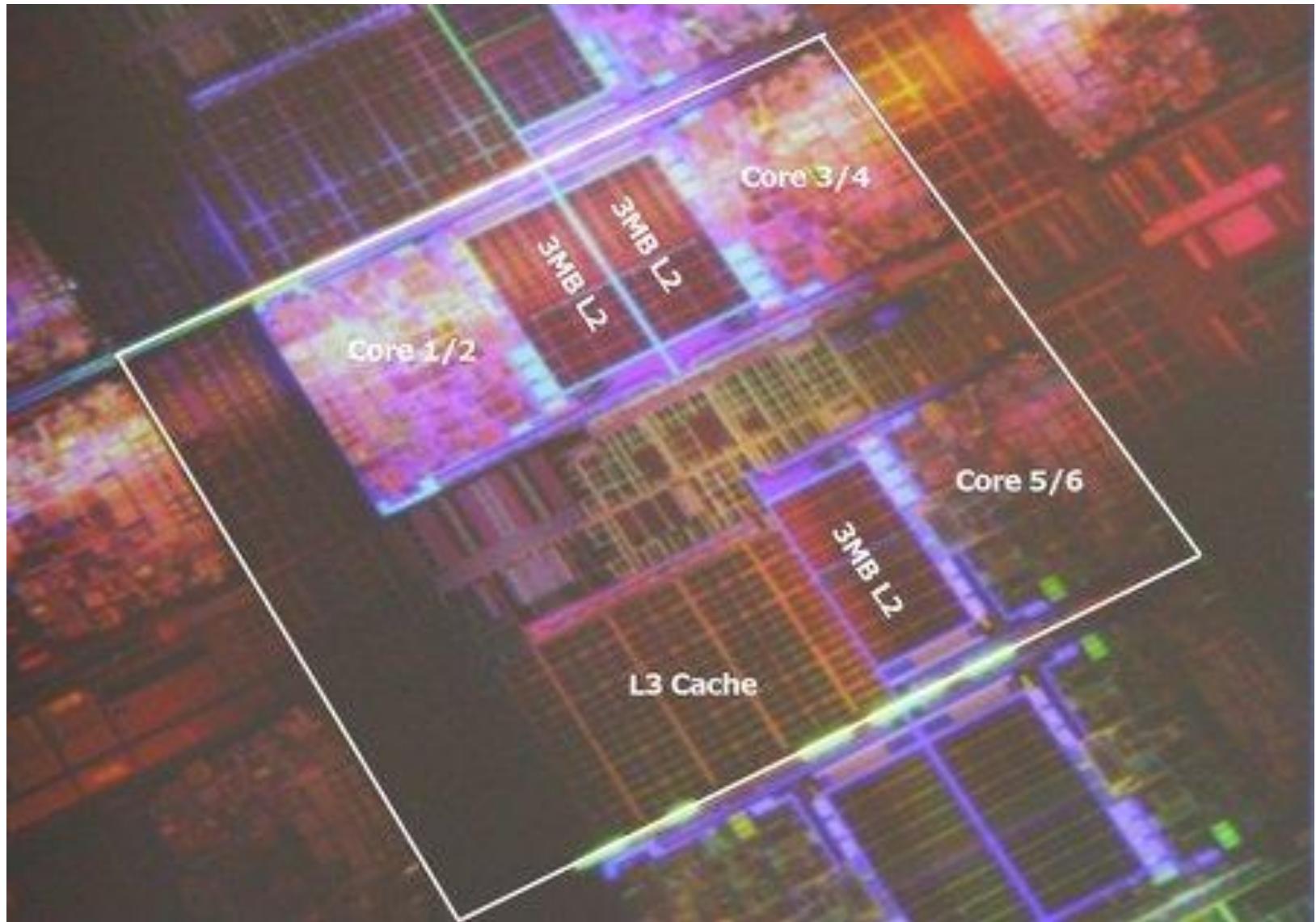
(2002)



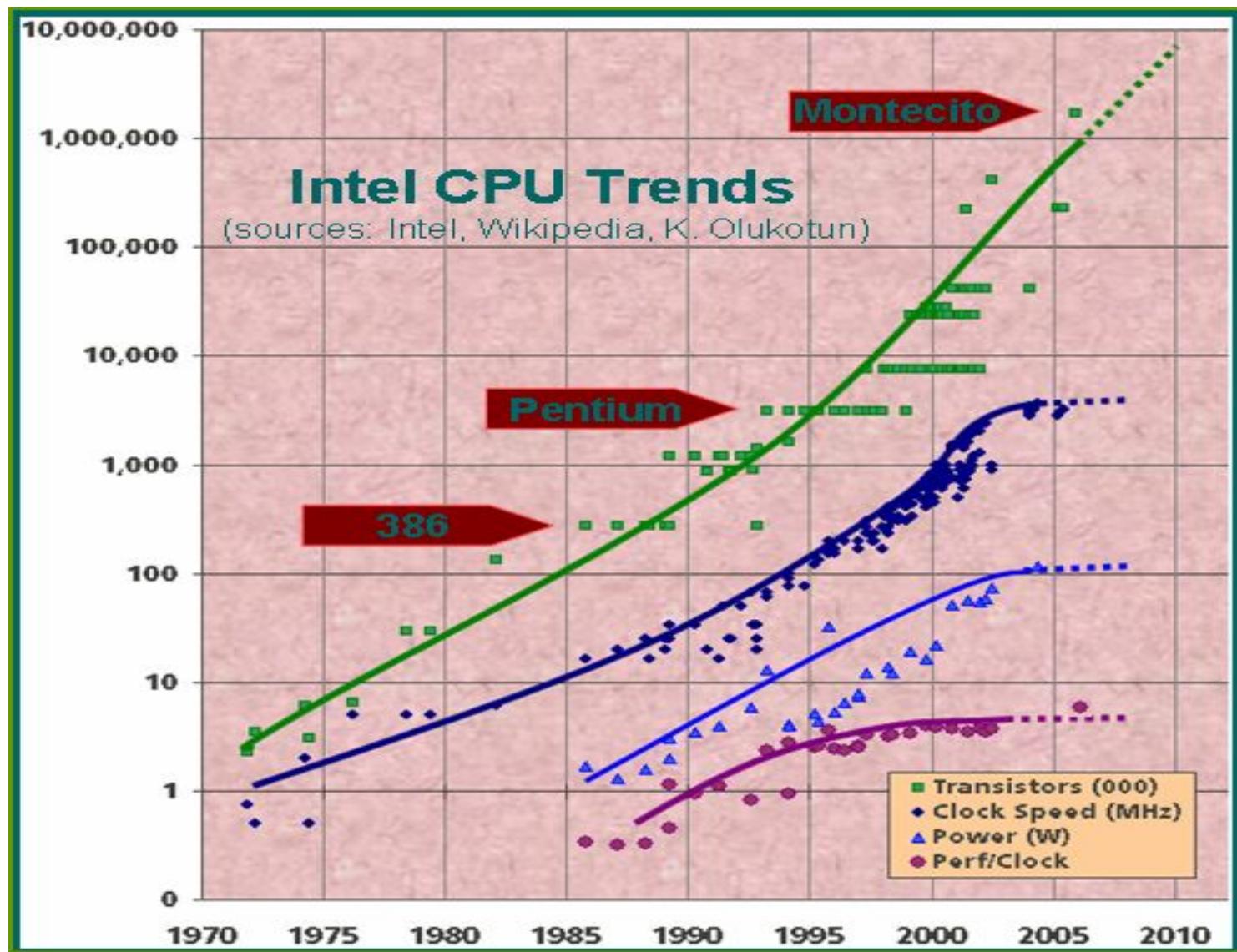
Tukwila 4 core Itanium, 2009



Intel Dunnington 6-core



How further?



Supercomputers

- IBM cluster
- 6480 nodes with
 - Dual core Opteron 1.8 GHz
 - 2 * PowerXCell 8i 3.2 GHz
(12.8 GFlops)
- Infiniband connection fabric (16 Gbit/s per link)
 - FAT tree interconnect
- 100 Tbyte DRAM memory
- 216 I/O nodes
- **2.35 MW** power
- MPI programming
- Size: 296 racks, **550 m²** *This is huge !!*

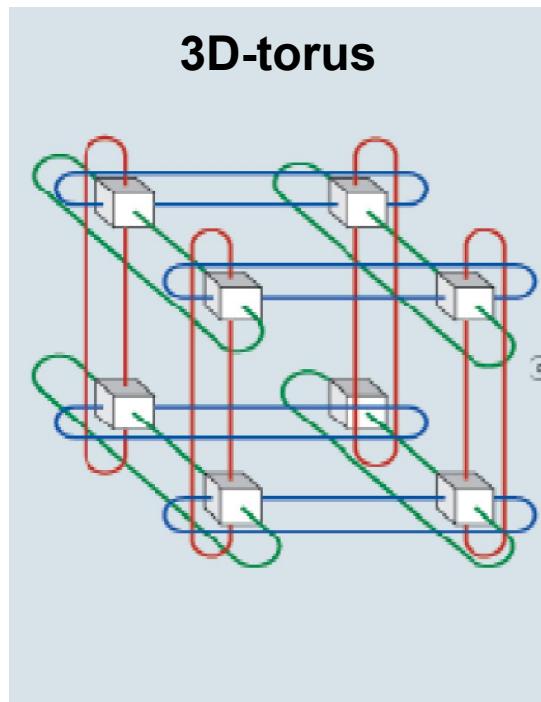


BlueGene/L IBM

- Based on ASIC with PowerPC 440, 700 Mhz, each 2.8 GFlops
- 105,496 nodes
- 3D Torus interconnect for p2p communication + Collective network



rack

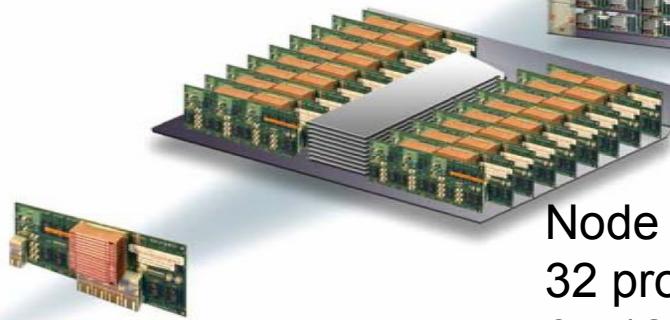


Complete system

Data Center (IBM)



2009: BlueGene/P



Processor card:
one 4-processor chip 435 GFlops
ASIC: 13.6 GFlops
13.6 Gflops 2-4 GB
8 MB EDRAM

Node card:
32 processor cards
64-128 GB

435 GFlops

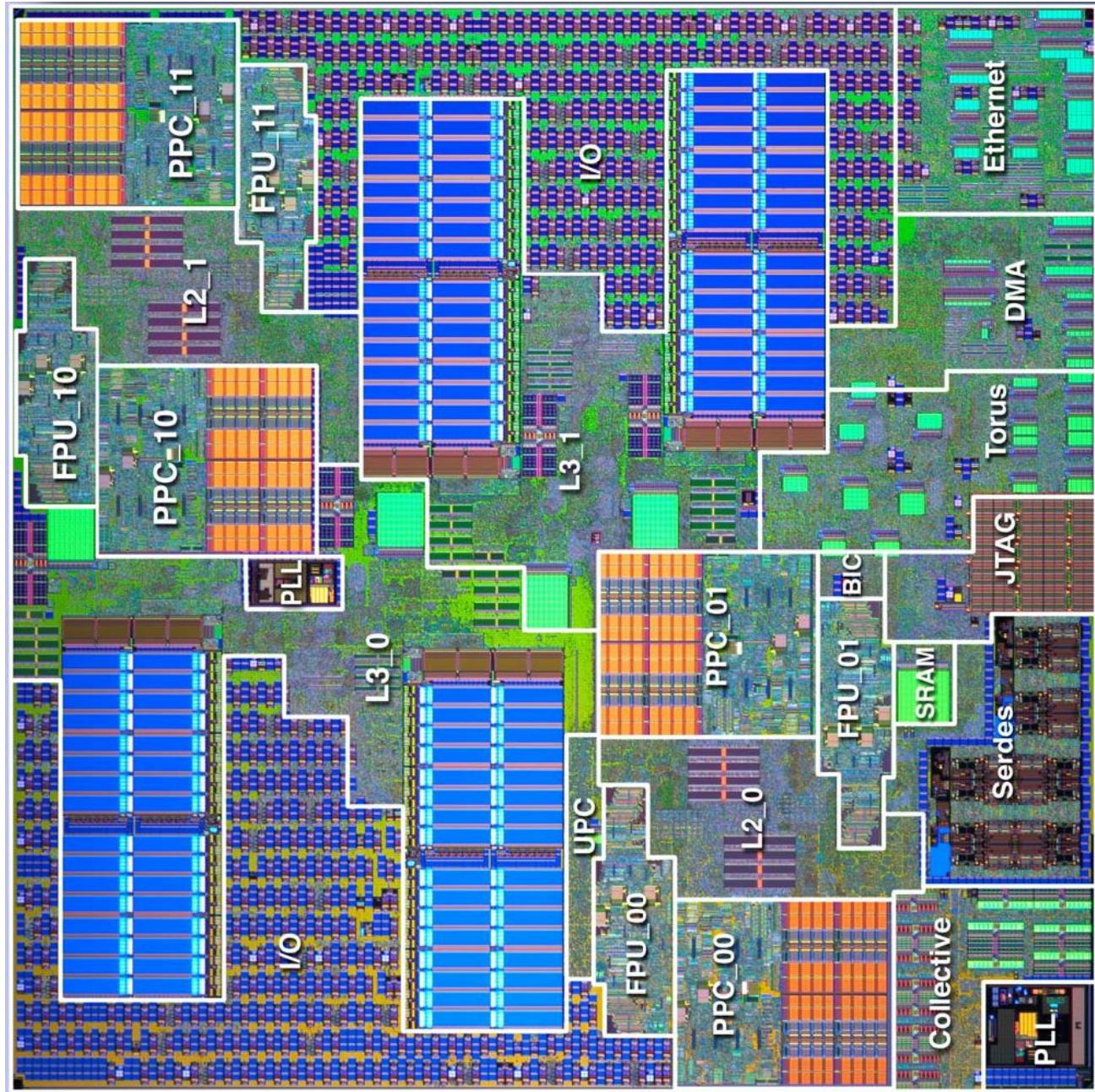


System:
256 racks
upto 1PB
3.56 PFlops

Rack:
32 Node Cards
13.9 TF/s
2-4 TB

BlueGene/P ASIC

- 208M trans
- 850 MHz
- 16W
- 90nm



BlueGene/L Node board



- 16 cards with 2 ASICs each
- 8 GB
- 180 Gflop

BlueGene/P node card



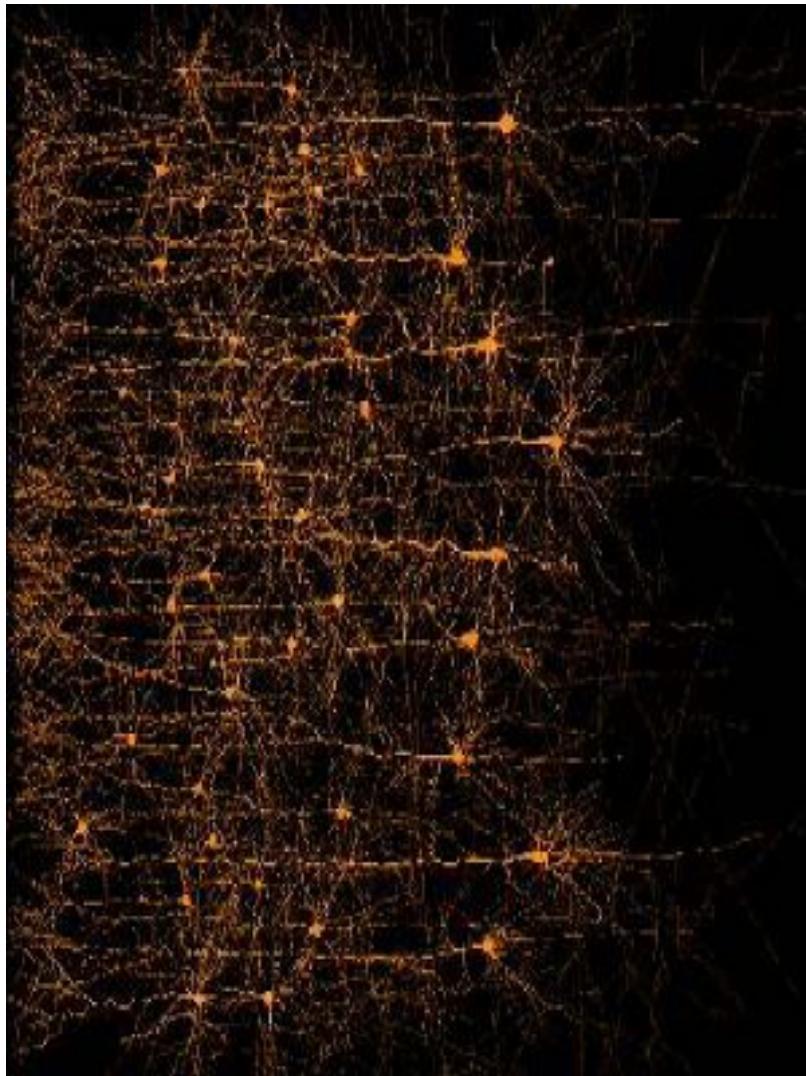
BlueGene/P rack



Can we match the human brain ???

- Performance = 100 Billion (10^{11}) Neurons * 1000 (10^3) Connections/Neuron * 200 ($2 * 10^2$) Calculations Per Second Per Connection = $2 * 10^{16}$ Calculations Per Second
- Memory = 100 Billion (10^{11}) Neurons * 1000 (10^3) Connections/Neuron * 10 bytes (information about connection strength and address of output neuron, type of synapse) = 10^{15} bytes = 1 PB = 1000 TB
- *How far off are we?*

Blue brain research



- Software replica of a column of the neocortex
 - 85% of brains total mass
 - required for language, learning, memory and complex thought
 - the essential first step to simulating the whole brain
- Next: include circuitry from other brain regions and eventually the whole brain.

Incredible Computer Ads!

**Now you can get our disk systems
within 30 days ARO at the
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Sunnyvale HQ: (408) 732-1650. **Canada:** (416) 624-0320. **United Kingdom:** (4482) 70725.
Germany: 211-477342. **Sweden:** 08-388440. **Spain:** 45-7-5312.

System Industries: "80 MB for under \$12,000" (1977)

RAM Card!



**The new 16K RAM card that turns
your computer into a
working giant**

**Available now —
store/factory**

Here's the industry's leading 16K RAM card.

It has two outstanding features that make it important to you:

(1) It's fast! It operates up to 4 MHz with no wait states. That's important because it lets you run programs on your Cromemco Z-8 and Z-2 computers in about half the time required by other systems. Even, if your present computer is not 4 MHz fast, this new Model 16KZ RAM eases you for the time when you'll need and want higher computer speed.

(2) It has Cromemco's Bank-Select feature. Bank-Select lets you expand memory far beyond 64K bytes. Not just beyond 64K, but far beyond — up to 512K bytes if you wish. Again, with Cromemco you get present outstanding performance plus obsolescence protection.

Bank-Select lets you organize memory into 8 banks of 64K each. The active bank is software-selected.

A useful giant

Whatever your S-100 bus computer — Cromemco, Altair 8800 or IMSAI 8080 — you can have enormous memory with the new Model



16KZ... You can run the large programs and files that make computers truly valuable — that take them out of the toy class and make them useful, producing units.

With Bank-Select you can even operate an S-100 bus computer as a time-share computer with up to 8 stations. A given memory bank can be accessed only by one station, so there is full confidentiality.

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Cromemco with our strong engineering staff is the only manufacturer to offer such a card.

And notice that this advanced card is available and ready for delivery — at your store or from the factory.

16K RAM memory kit
(Model 16KZ-K) \$495.
16K RAM memory assembled,
tested, and burned in for 360
hours (Model 16KZ-W) \$795.

Memorade and Busmemode offered with signed order. Memorec and Memorec II offered with signed order. All 16K RAM cards are 100% tested.



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Cromemco: "The New 16K RAM card..." (circa 1977)

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Save \$100 With This Incredible Offer From Radio Shack!

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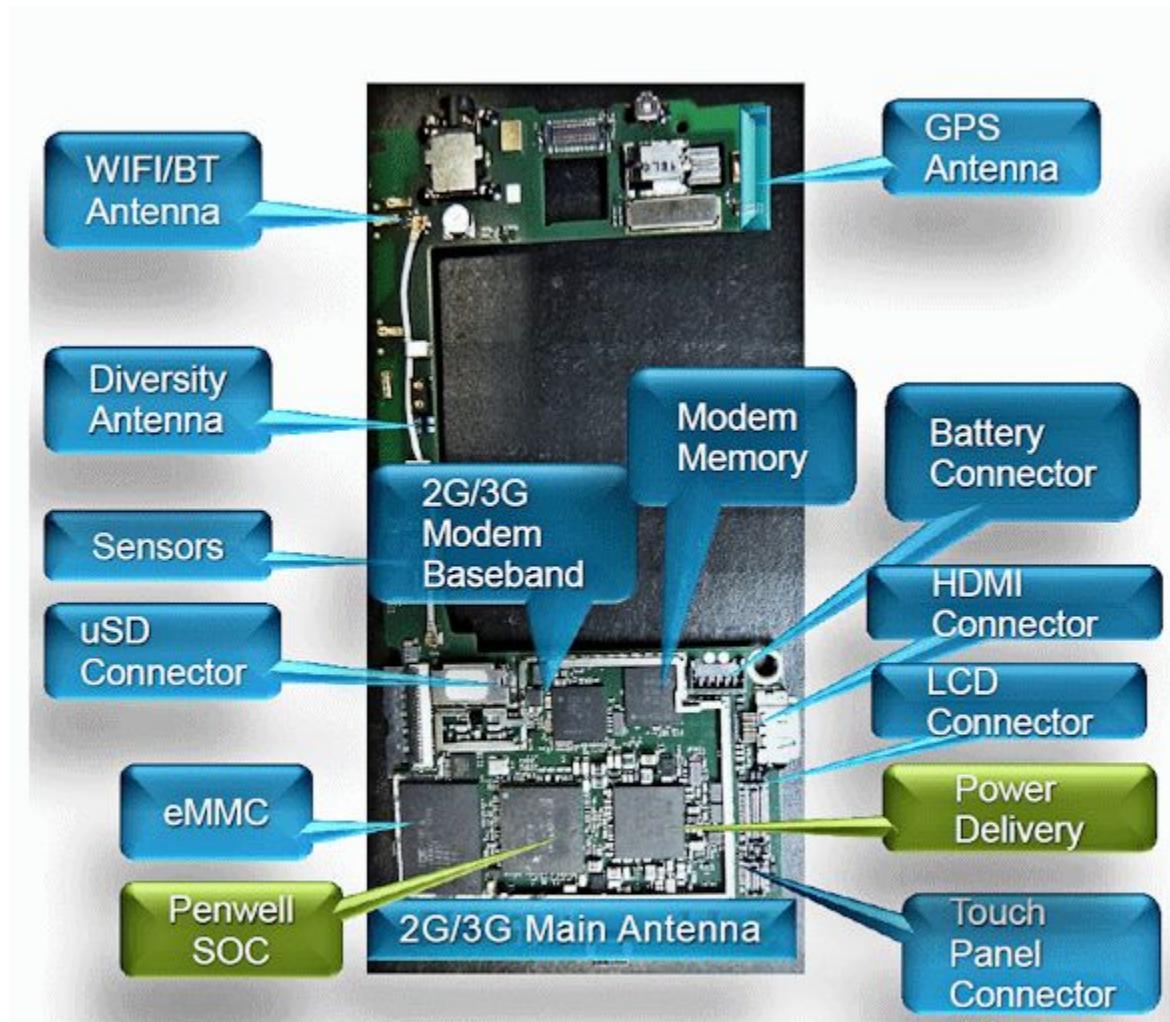
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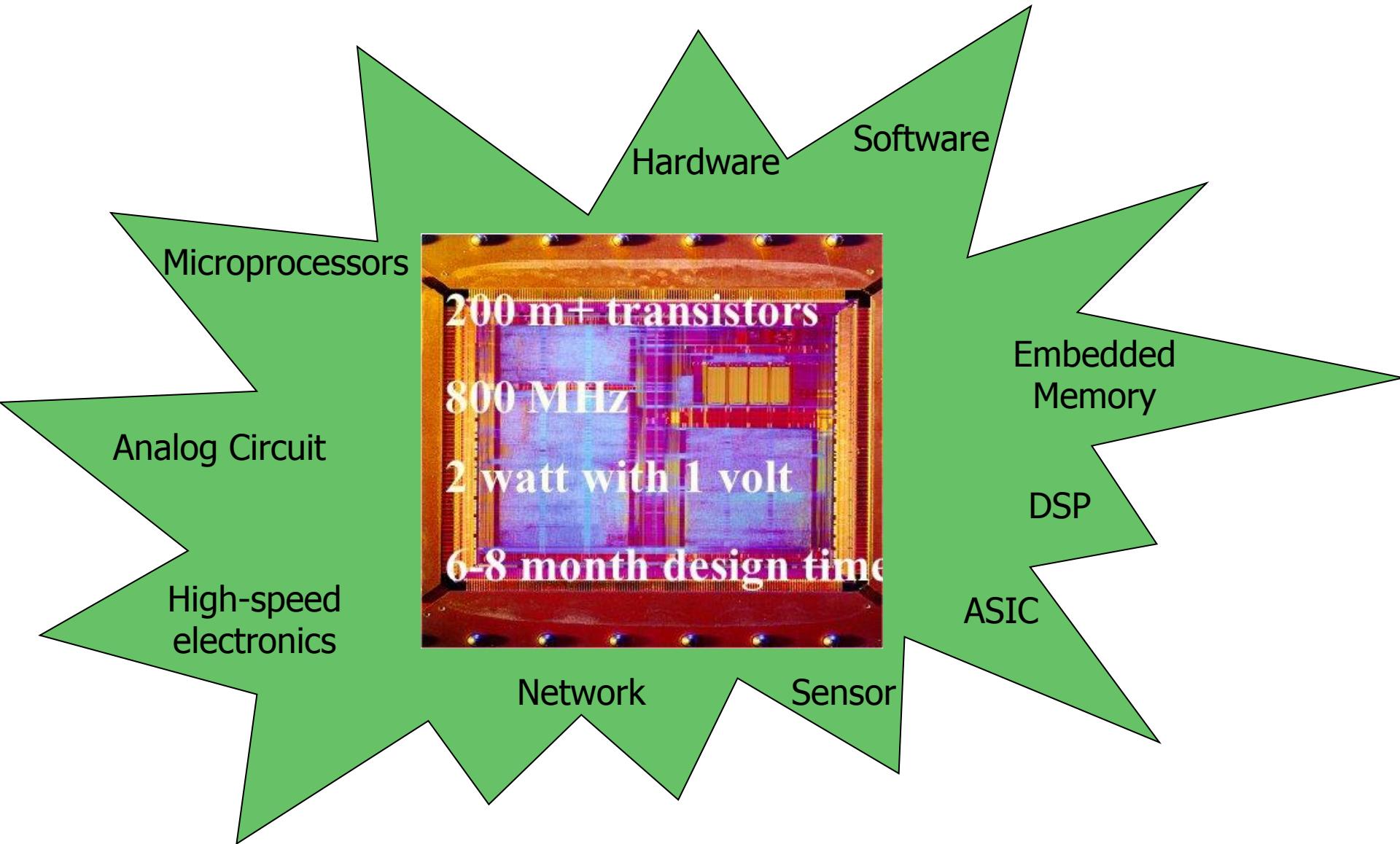
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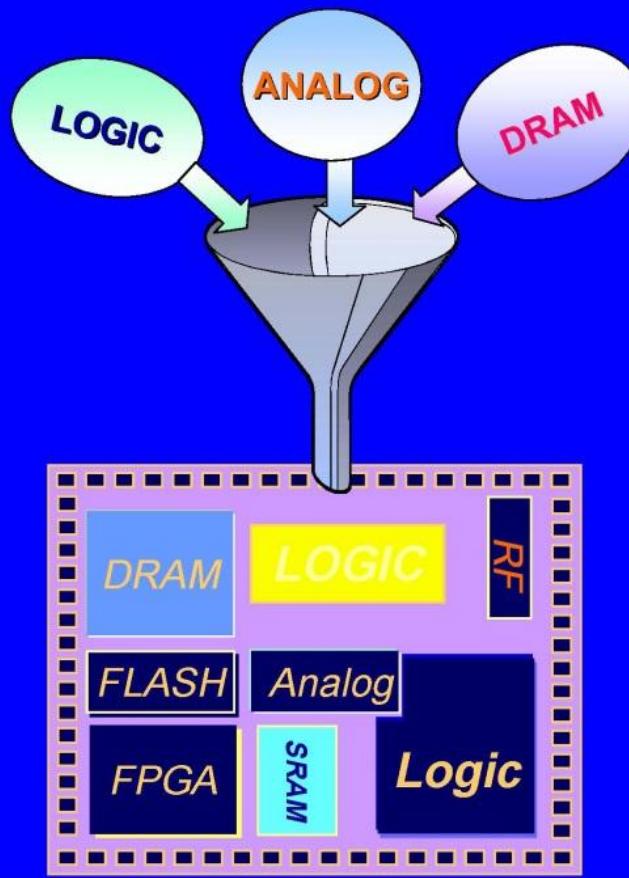
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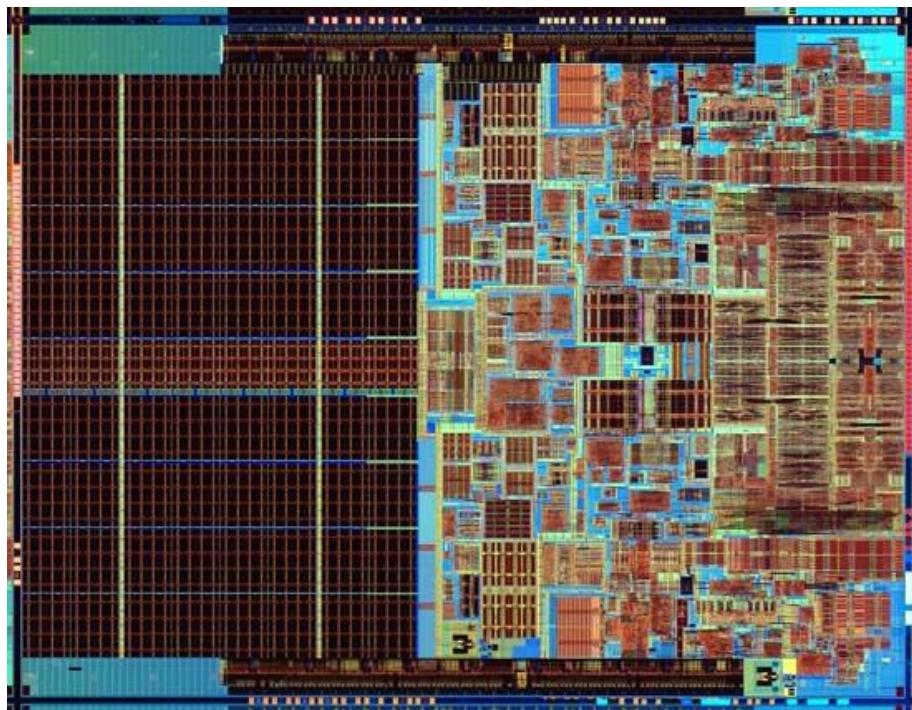
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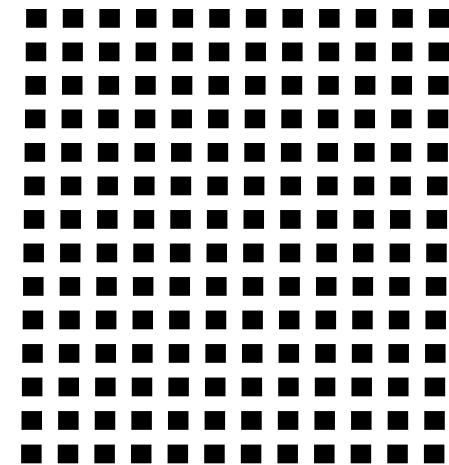
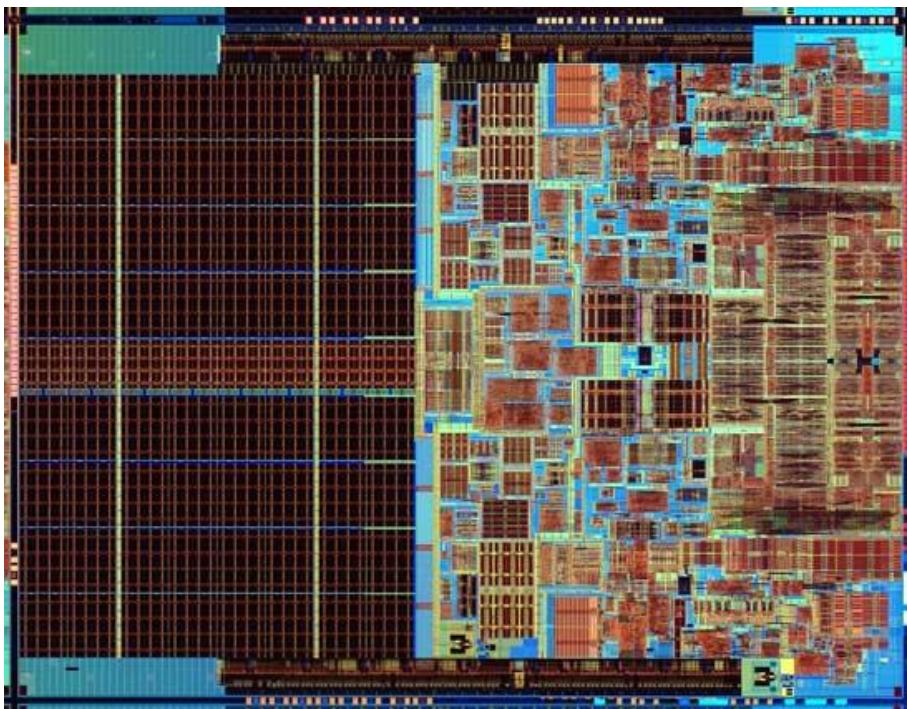
At The End

What you should have
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At The End

The **actual**
processor size



The technology behind
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